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ENERGY EFFICIENCY OF BUILDINGS IN CITIES

Volume III: Working Papers

Paper No. 3: Financial Analysis of Six Prototypical Apartment Buildings: Background Information and Assumptions

Paper No. 4: Methods and Detailed Calculations Used in Estimating the Retrofit Potential of Different Building Types

December 1982

CONGRESS OF THE UNITED STATES
Office of Technology Assessment
Washington, D. C. 20510

Preface

This volume contains papers written for OTA to assist in preparation of the report *Energy Efficiency of Buildings in Cities.* OTA does not endorse these papers. In several instances, the OTA report reaches somewhat different conclusions because of additional information which was obtained later. These papers, however, may prove valuable for readers needing more detailed or specific information than could be accommodated in the final assessment report, and are being made available for such purposes.

WORKING PAPER

#3

Financial Analysis of Six Protypical Apartment Buildings: Background Information and Assumptions

Real Estate Research Corp.
Chicago, Ill.

With Introduction by
OTA Staff

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- Impacts on Return (MIRR)

Detailed Tables

- Projected Income and Expenses 1975-85
- Sets of Tables for Each Prototype
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  - Proforma Investment Analysis

Introduction to Financial Analysis of Six Prototypical Buildings

This working paper presents an analysis of the financial impact of an energy conservation retrofit on six prototypical buildings. The analysis was performed by Real Estate Research Corporation (RERC) of Chicago as part of a broader analysis of the likelihood that building owners would invest in energy conservation. The project as a whole formed the basis for Chapter 4 of the full Buildings in Cities report. The analysis shown in detail in this working paper was used as the basis for the analysis of cash flow impacts of energy retrofits on pp. 135-138 of Chapter 4.

The six buildings analyzed are six apartment buildings in three climate zones. The buildings do not exist; descriptive financial data is constructed from several sources as explained in the methodological introduction by Real Estate Research.

The packages of energy conservation measures installed for each building are meant to be illustrative only. Expected savings from the packages would result in simple paybacks ranging from six to nine years. Because the paybacks are moderately long, the cash flow problems for the buildings are more severe than they would be for retrofits with shorter payback periods.

One of the purposes of the prototype financial analysis is to evaluate the impact on cash flow of two different forms of financial assistance -- a 30% tax credit and a financing subsidy which has the combined impact of lengthening a loan term from 5 to 10 years and reducing the interest rate from 16 to 13%. There is one assumption made for analytical convenience in handling the computer program which does not actually correspond to current tax reality but which does not alter the basic finding on the impact of the two options on cash flow. It was assumed that the 30% tax credit would substitute for 30% of the depreciation allowed on the investment thus permitting only 70% of the investment to be depreciated. The result of this is equivalent to a highly accelerated 100% depreciation schedule in which the first year's depreciation is the credit plus the normal first year depreciation but the depreciation schedule is shortened. In fact under current tax law, the investment tax credits and energy tax credits may be taken in addition to full depreciation.

This assumption, however, doesn't invalidate the general conclusion of the analysis that the tax credit will greatly improve the first year's cash flow but may create a cash flow shortage in later years after the tax benefits run out but before the debt service is paid off.

The working paper which follows presents RERC's description of the data sources and analytical methods used in the prototype analysis, followed by three summary tables and two sets of detailed tables which present information on each of the six prototypical buildings.

The RERC staff responsible for the analysis were Stephen B. Friedman and Glenn Whitmore.

APPENDIX 3

BUILDING PROTOTYPE FINANCIAL ANALYSIS BACKGROUND INFORMATION AND ASSUMPTIONS

Objectives

The objective of conducting pro forma financial analysis on existing income properties in selected climate zones was to test for the effect on cash flow performance and rates of return resulting from an investment in energy saving building improvements. The task involved:

- Selection of typical buildings in a variety of climate zones.
- Projecting financial performance under normal operating conditions.
- Deriving the overall investment return given a likely holding period and resale.
- Repeating the financial tests to estimate the impact of alternative energy investment packages on capital, expenses, cash flow, resale value, and the resulting equity yields.

Development of Building Prototypes

The general building parameters followed in selecting and constructing the prototype pro forma operating statements were as follows:

1. The analysis was limited to multi-family rental apartment buildings in climate zones 1, 2, and 4 as designated in Energy Works, Inc.'s technical analysis. These climate zones correspond to average heating and cooling conditions found in Buffalo, St. Louis and Tampa for purposes of energy budget and retrofits.
2. A total of six different prototype buildings were developed with a small and large building designated in each climate zone.
3. The small building was intended to be 15-24 units, 2 to 3 floors, and a walk-up type structure constructed in the 1960's.
4. The large building was targeted as an 80-135 unit, 6-10 floors, elevator building constructed during the same time period.

Each building was assumed to be in an in-city location (as opposed to a suburban location) within a major metropolitan area. We selected 800 square feet as the average target apartment size for the purposes of the study.

Using these general parameters as guidelines, typical income and expense data were compiled. These figures were then checked for reasonableness and trend projected for each building relying heavily upon the following information sources:

1. Actual RERC appraisals, market and feasibility studies of specific, apartment properties, where appropriate and applicable.
2. Interviews with local building owners, appraisers and realtors in target cities within the selected climate zones.
3. Institute of Real Estate Management, Apartment Income/Expense Analysis Surveys, 1975 through 1980.
4. Telephone interviews with local government property assessors and officials of taxing authorities.
5. Telephone interviews with local utility company officials in the selected climate zones to confirm energy cost magnitudes and recent cost increases.

While the prototypes do not correspond to actual buildings in any particular city, the general economic conditions of a metropolitan area like Minneapolis/St. Paul would correspond to climate zone 1, St. Louis to climate zone 2, and Tampa to climate zone 4.

In addition to the above information sources, the prototype pro forma operating statements used as the basis of analysis were reviewed by Mr. Denis Gathman, Vice President and Director of Appraisal (Chicago office) for Real Estate Research Corporation. Mr. Gathman is a member of the Appraisal Institute (MAI) and a Senior Real Property Appraiser. He has made over 6,000 appraisals, many of which were multi-family apartment buildings similar in type, size and age to the prototypes developed in our report. His reviews were particularly helpful in projecting income and expense items, achieving likely expense to income ratios and selecting appropriate capitalization rates to estimate market (investment) value for each property.

Unit and square footage data on each prototype building are as follows:

	Number of Units	Rentable*	
		Total Square Footage	Square Footage Per Unit**
Climate Zone 1:			
Small Building	18	15,360	853
Large Building	133	107,216	806
Climate Zone 2:			
Small Building	25	21,500	860
Large Building	125	87,500	700
Climate Zone 4:			
Small Building	19	19,500	1026
Larbe Building	100	76,545	765

*Rentable space generally excludes corridors, hallways, stairwells, and other common areas from which no rental revenue is generated.
**Rounded

It should be emphasized that the protype buildings are assumed to be quality investment grade structures built to code by a professional developer and not by an owner. It was assumed that the buildings were in good condition at the time of purchase and that no major capital improvements other than minor repairs and maintenance, painting and carpet shampooing were necessary subsequent to acquisition.

Method of Financial Analysis

The pro forma, cash flow operating statements for each of the prototype buildings were projected using the Mike Robbins Cash Analysis Computer Program (MRCAP) available through the Eductional Foundation for Computer Applications In The Real Estate Industry Inc. (EDUCARE).

The MRCAP program is an advanced cash flow program designed to provide for the simulation of a wide array of investment strategies associated with real estate ownership. The program performs cash flow analysis and financial projections for projects owned by individuals, corporations or partnerships (both general and limited), for any holding period up to 25 years. The program allows for the identification of fifteen (15) capital assets financed with up to eight mortgages and distributed to a maximum of fifteen partnerships. Primary output consists of:

- A summary of income and expense assumptions
- A summary of other financial input

- Depreciation summary
- Mortgage assumptions
- Cash flow analysis including annual pro forma operating statements for each year of the holding period
- Before and after tax yield calculations

Basic Prototype Assumptions

It was assumed that each of the buildings was purchased in December 1978 with a conventional mortgage financing package including an annual interest rate of 11.25%, a 25 year term, and a 75 percent loan to value ratio . A holding period of seven years was assumed from the time of purchase with a presumed sale occuring at the end of year 7 (1985). Component, straight line depreciation was used in order to achieve maximum asset write-off and tax shelter and further to avoid the excess depreciation "tax trap" normally experienced when accelerated depreciation methods are used.*

> *In the past, taxpayers were able to convert sizable amounts of ordinary income into capital gain by taking accelerated depreciation on real property used in a trade or business or held for the production of income and realizing capital gains on a later sale.
>
> In the Revenue Act of 1964, rules were enacted providing for the recapture of accelerated depreciation upon sale of the property.
>
> In spite of this, ordinary income could still be converted into capital gain because there was no recapture if the taxpayer held the property for 10 years or more before selling it (partial recapture between 21 months and 10 years).
>
> The Tax Reform Act of 1969 reduced these tax-benefit opportunity by limiting accelerated depreciation methods for real property and providing for 100% recapture of post-1969 excess depreciation

The individual owner/partner was assumed to have a marginal income tax rate of 50% for federal income tax purposes. An equity discount rate of 12% was used to present value any equity contributions made to the building after the initial purchase. The discount rate or equity yield rate is traditionally interpretated as the annual percentage rate that reflects the competitive rate of return on total capital or equity capital invested in a building.

It was further assumed that the spendable after tax cash flows generated each year from the building would be reinvested in a money market fund or equivalent investment earning 8.50% interest annually.

Resale costs and expenses associated with selling the property at the end of the seven year holding period were assumed to be 7 percent of the market (investment) value of the building at the time of sale. End of year market (investment) value was determined by the net income capitalization approach as typically employed in professional appraisal techniques. This approach involves conversion of the annual net operating incomes (NOI) produced by the building into an estimated value through division by a capitalization rate on multiplication by the net income multiplier (the inverse of the capitalization rate.) The capitalization rate is explained in a later section of this Appendix. Table A-3-1 provides a summary of the financial input and income/expense assumptions pertinent to the "base case" cash flow calculations for each building in each of the three selected climate zones. The "base case" runs involve no energy retrofit improvements and portray the financial status quo of the building "as is".

To project energy expenses it was assumed that energy costs would experience 5% real growth in climate zones 1 and 2, and 2% real growth in climate zone 4, over and above the nominal, inflation driven increases exhibited in all other operating expenses in each building. The projections assume a base rate of inflation between 9 and 11 percent. No major jolts to either the national or local financial markets in each climate zone are assumed during the period of analysis. In addition, no local real estate market and/or economic anomolies such as threats of rent control, major employer plant shutdowns, or large scale employee layoffs are anticipated.

Energy Retrofit Test and Assumptions

A moderate level investment in energy saving improvements was assumed to be made at the end of year 2 (1980) of the holding period. The cost per square foot to the owner and resulting total investment for each building were as follows based on information provided by Energyworks, Inc. in their report of November 25, 1980:

	Medium Energy Retrofit Costs	
	Per Square Foot	Total Investment
Climate Zone 1:		
Small Building	$1.452	$ 22,303
Large Building	1.160	124,371
Climate Zone 2:		
Small Building	1.619	34,809
Large Building	1.081	94,588
Climate Zone 4:		
Small Building	0.815	15,893
Large Building	0.546	41,794

Investments of this magnitude were assumed to result in a 30% reduction in energy expenses from the Base Case for each building.

Table A-3-1 Financial Inputs and Economic Charteristics
Of The Selected Protoype Buildings

	Climate Zone 1		Climate Zone 2		Climate Zone 4	
	Small	Large	Small	Large	Small	Large
*Gross Rent	$ 84,609	$ 626,439	$ 84,938	$ 439,170	$ 68,881	$ 454,061
*Expenses	$ 29,817	$ 225,685	$ 38,946	$ 217,043	$ 23,062	$ 155,092
* Real Estate Taxes	$ 14,292	$ 96,181	$ 5,596	$ 11,567	$ 7,212	$ 45,828
*Vacany Rate + Collection Losses	.03	.03	.09	.08	.03	.05
Ration of Expenses to Groos Rent	.35	.36	.47	.49	.33	.34
Initial Cost	$297,880	$2,547,280	$271,320	$1,456,525	$335,155	$2,114,522
*Annual Rate of Growth of Gross Rent	.0815	.0825	.0733	.0805	.0757	.0882
*Annual Rate of Growth of all Expenses	.1302	.1407	.1321	.1320	.1066	.1126
*Annual Growth Rate of Energy Expenses	16%	17.2%	15.2%	14.0%	11.6%	12.5%
Going-On Capitalization Rate	9.5%	9.2%	10.5%	10.2%	9.0%	8.3%
Going-Out Capitalization Rate	11.0%	10.1%	10.96%	11.4%	9.4%	9.2%

*Average for the 7 year holding period.

Three alternatives financing packages were tested in support of the investment:

1. Fundamental Package

   - 100% Energy Investment Loan Financing
   - 16% Annual Interest
   - 5 Year Term
   - Entire Investment Depreciated Over a 12 Year Year Useful Life

2. Fundamental Package Plus Tax Credit

   - Tax credit equal to 30% of the investment granted in Year 3 (1981)
   - Depreciation taken on the remaining 70 percent of the investment over a 12 year useful life.

3. Modified Package

   - 100% Energy Investment Loan
   - 13% Annual Interest
   - 10 Year Term
   - Entire Investment Depreciated Over a 12 Year Useful Life

Key Indicators of Financial Status

Five indicies of financial performance were selected to gauge the financial impact of the energy retrofit packages:

a.) Net Operating Income. Annual net operating income (NOI) is the income remaining after deducting vacancy/bad debt allowances, fixed, variable and capital replacement expenses but before deducting debt service and income tax. NOI is used in a variety of calculations to determine risk potential and return performance of an investment property.

b.) Cash Throw-Off is the cash available to the owner/investor after operating expenses and contractual debt service are covered. It is the pre-tax cash flow generated by building revenues which is available to any investor as a return on the original equity investment. The ratio of cash throw-off to the original equity invested in the building is commonly referred to as the before tax cash on cash return.

c.) Spendable Cash After Taxes is the after tax cash flow. It is normally made up of the cash generated from building operations plus any implicit tax sheltered cash resulting from a negative income tax obligation if present. The tax savings created by the transfer of a building-generated negative tax liability to the investor's personal tax return are most attractive to investor's in higher tax brackets who want to maximize the after tax income from a number of income sources.

d.) Modified Internal Rate of Return (MIRR) With Sale. The modified or financial manager's internal rate of return specifies a reinvestment rate prior to generating a yield calculation. The final yield is that discount rate which equates the expected after tax cash flows with the initial cash outlay. The modified IRR represents the overall investment return from the building including the potential capital gain or loss resulting from an assumed reversion or resale.

The MIRR calculation involves reinvesting the annual after tax proceeds from the building and compounding them forward to the resale date. These cash flows are next combined with the after tax reversion proceeds and then the resulting "bundle" of income is discounted back at a rate which makes the initial capital cost of the investment equal to the present value of the annual cash flows and reversion value. Mathematically the calculation works as follows:

Year	Spendable Cash After Taxes		Reinvestment Rate Factor (Future Value Factor @ 8.5%)		F. V. of Spendable Cash After Taxes
1	SCAT 1	*	1.6314675	=	XXXX
2	SCAT 2	*	1.5036567	=	XXXX
3	SCAT 3	*	1.3858587	=	XXXX
4	SCAT 4	*	1.2772891	=	XXXX
.	.				
.	.				
.	.				
.	.				
7	SCAT 7	*	1.00000	=	XXXX
	Sum of Spendable Cash After Taxes				XXXX
	+ After Tax Profit (Loss) From Sale			+	XXXX
	= Future Value of Equity Benefits			=	XXXX

$$\text{Zero Net Present Value} = \text{Present Value of the Equity Investment} - \left[\text{F. V. of Equity Benefit} * \frac{1}{(1+i)}^{7} \right]$$

Modified IRR calculation solves for i.

Summary of Financial Analysis Tests

Tables A-3-2 through A-3-7 summarize the results of the financial analysis projections for each of the prototype buildings under the base case (no energy retrofit) and under the three alternative energy retrofit packages. The five key indicators of financial status were examined in three critical years of the holding period: 1.) 1980 - pre-energy retrofit investment 2.) 1981 - post-energy retrofit investment and 3.) 1985 - assumed year of sale of the building. Copies of the full cash flow print-outs for each computer run are provided at the end of this Appendix.

In summary, the results indicate that for those buildings where energy expenses represent the highest proportion of costs in relation to all other expenses, the energy retrofit investment yields the greatest improvement in net income, cash flow, estimated market (investment) value, and total investment return. From another standpoint, the financial incentive to make the investment would logically appear to be greatest for those building owners who carry the bulk of the energy costs for their tenants and are not able to pass through utility cost increases in a timely fashion through renegotiated rents or metering the building. The financial impacts of the energy investment seem logical, given our critical assumption that a 30 percent reduction in energy costs will be realized from the improvements and that energy costs are rising 2 to 5 percentage points greater than other expenses.

The modified energy investment financing alternative (13% annual interest for a five year term) appears to yield-the best overall financial results across all five financial indicators over the entire holding period. The 30% one-time tax credit option brings the best overall investment return, but its benefit is only marginal in comparison to the modified financing alternative (13% annual interest, five year-term), and the only cash flow line improved is after tax cash flow in one year exclusively - 1981 - the year that the credit is granted. Other financial indicators for other years do not show significant benefit.

Critical Assumptions, Limitations and Sensitivities

Real estate investment analysis seldom enjoys a rigid set of project specifications. Uncertainty in today's real estimate markets can have a drastic effect on practically every building variable used in our analysis.

A high degree of sophistication in a cash flow analysis is certainly no guarantee that a derived estimate of investment value or overall return will in fact be realized for a given building.

In our analysis there are several critical assumptions on which the results are fundamentally based:

1. The apartment buildings examined are not actual proterties, but rather prototypes envisioned to reflect operating characteristics typical of the type of building sought to be tested in the specified climate zones and held during the financial market conditions from late 1978 to the present.

2. The hypothetical test for financial impact resulting from an energy conserving investment hinges entirely on the assumption that a 30% reduction in energy expenses experienced by the owner from the base case will result if the energy improvements are implemented.

3. The capitalization rates selected to value the building at a "going-out" sale price play a powerful role in determining market (investment) value and overall investment return. The capitalization rate is generated from market verified comparable sales information in addition to an assembled set of investor and lender established financial variables. A properly determined capitalization rate should be a highly specialized, project and market specific variable. We have attempted to select capitalization rates which make practical sense given our knowledge of the general market conditions in the specified climate zones and selected target cities within the climate zones. To derive capitalization rates with the exactitude demanded in a professional appraisal of an actual property, would have been beyond the intended scope of this project.

SUMMARY TABLES

Distribution of Total Expenses, National and RERC Prototypes (Percent)

Impact on Return (MIRR) After Sale

Returns (MIRR) with Sale, Climate Zone 4

DISTRIBUTION OF TOTAL EXPENSES, NATIONAL AND RERC PROTOTYPES
(PERCENT)

	Small Apartments								Large Apartments							
	National		CZ 1		CZ 2		CZ 4		National		CZ 1		CZ 2		CZ 4	
	1970	1979	1975	1979	1975	1979	1975	1979	1970	1979	1975	1979	1975	1979	1975	1979
Administrative	11.2	13.6	12.9	11.5	7.7	6.0	9.4	8.1	12.4	14.7	124.2	15.0	18.6	16.2	15.3	16.2
Maintenance/Repairs	18.7	19.5	12.1	16.3	26.5	28.4	15.1	17.2	14.5	16.5	12.8	14.1	30.2	30.4	25.4	27.0
Taxes	30.8	20.7	50.3	42.6	25.1	19.7	34.0	35.5	29.0	23.7	44.5	38.4	13.2	10.9	32.0	29.3
Other	20.6	13.7	8.0	7.6	4.2	5.2	16.3	11.0	30.4	15.2	10.2	11.7	11.0	11.2	13.2	12.9
Energy	18.7	32.5	14.1	18.5	35.1	39.1	17.6	19.7	13.7	29.9	15.7	17.9	25.1	28.9	11.1	11.5
Other Utilities	NA	NA	2.7	3.5	1.5	1.6	7.6	8.5	NA	NA	2.4	2.7	2.0	2.3	2.9	3.1
Total	100.0	100.0	100.1	100.0	100.1	100.0	100.1	100.0	100.0	100.0	99.9	99.8	100.1	99.9	99.9	100.0

Sources: Institute of Real Estate Management and Real Estate Research Corporation.

IMPACT ON RETURN (MIRR)* AFTER SALE

Building	No Retrofit Base MIRR	Alternatives					
		16%/5 yrs.		13%/10 yrs.		30% Tax Credit	
		MIRR	Change	MIRR	Change	MIRR	Change
Small, CZ 1	.157	.189	.032	.190	.033	.190	.033
Large, CZ 1	.132	.163	.031	.164	.032	.164	.032
Small, CZ 2	.100	.180	.080	.181	.081	.182	.082
Large, CZ 2	.114	.161	.047	.162	.048	.163	.048

*MIRR is Modified Internal Rate of Return

Source: Real Estate Research Corporation

RETURNS (MIRR)* WITH SALE, CLIMATE ZONE 4

	No Retrofit MIRR	16%/5 yrs.		13%/10 yrs.		30% Tax Credit	
		MIRR	Change	MIRR	Change	MIRR	Change
Small Building	.145	.166	.021	.166	.021	.167	.022
Large Building	.157	.170	.013	.170	.013	.170	.013

* MIRR is Modified Internal Rate of Return.

Source: Real Estate Research Corporation

DETAILED TABLES

Tables A1-A6: Prototype Buildings Projected Income and Expense 1975-85

Set of Tables for Each of the Six Prototype Buildings as Follows:

- Energy Retrofit Tests (1 page) showing the impact on financial indicators of each retrofit financing package
- Proforma Investment Analysis (3 pages)

TABLE A1: PROTOTYPE BUILDING

PROJECTED INCOME AND EXPENSE

BUILDING: SMALL APARTMENT, CLIMATE ZONE 1 (OWNER UTILITIES)

	1975		1980 BASE		1981				1985			
					TREND		RETROFIT		TREND		RETROFIT	
	Money	Percent Expense	Money	Percent Expense	Money	Percent	Money	Percent	Money	Percent	Money	Percent
Real Estate Tax	10,138	46.1	12,902	36.0	13,547	34,4	13,547	36.7	16,467	28.5	16,467	30.9
Energy Expense	3,096	14.1	7,066	19.7	8,197	20.8	5,738	15.6	14,841	25.7	10,388	19.5
All Other Expense	8,770	39.8	15,898	44.3	17,596	44.8	17,596	47.7	26,435	45.8	26,435	49.6
Total Expense	22,004	100.0	35,866	100.0	39,340	100.0	36,881	100.0	57,743	100.0	53,290	100.0
Effective Gross Income*	46,725		69,112		74,702		74,702		101,981		101,981	
Energy/Income Ratio	6.6%		10.2%		10.9%		7.7%		14.6%		10.2%	
Expense/Income Ratio	47.1%		51.9%		52.7%		49.4%		54.6%		52.3%	

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* Gross Possible Income Less Allowance for Vacancy

Energy expense projected at 5% more than all other expenses, or 16%.

See report text for assumption.

SOURCE: Real Estate Research Corporation.

TABLE A2: PROTOTYPE BUILDING

PROJECTED INCOME AND EXPENSE

BUILDING: LARGE APARTMENT, CLIMATE ZONE 1 (OWNER UTILITIES)

	1975		1980 BASE		1981				1985			
					TREND		RETROFIT		TREND		RETROFIT	
	Money	Percent Expense	Money	Percent Expense	Money	Percent	Money	Percent	Money	Percent	Money	Percent
Real Estate Tax	67,546	42.5	86,845	33.8	91,187	32.1	91,187	34.1	110,839	25.7	110,839	27.7
Energy Expense	24,895	15.8	48,247	18.8	56,545	19.9	39,581	14.8	106,686	24.7	74,680	18.7
All Other Expense	66,344	41.7	121,690	47.4	136,293	48.0	136,293	51.1	214,460	49.6	214,460	53.6
Total Expense	158,785	100.0	256,782	100.0	284,025	100.0	267,061	100.0	431,985	100.0	399,979	100.0
Effective Gross/ Income*	352,741		513,986		556,284		556,284		763,571		763,571	
Energy/Income Ratio	7.1%		9.4%		10.2%		7.1%		14.0%		9.8%	
Expense/Income Ratio	45.0%		50.0%		51.1%		48.0%		56.6%		52.4%	

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* Gross Possible Income Less Allowance for Vacancy

Energy expense projected at 5% more than all other expenses, or 17.2%

See report text for assumptions

SOURCE: Real Estate Research Corporation

TABLE A3: PROTOTYPE BUILDING

PROJECTED INCOME AND EXPENSE

BUILDING: SMALL APARTMENT, CLIMATE ZONE 2 (OWNER UTILITIES)

	1975		1980 BASE		1981				1985			
					TREND		RETROFIT		TREND		RETROFIT	
	Money	Percent Expense	Money	Percent Expense	Money	Percent	Money	Percent	Money	Percent	Money	Percent
Real Estate Tax	4,800	22.1	5,375	15.2	5,483	14.0	5,483	16.1	5,934	9.8	5,934	11.5
Energy Expense	7,642	35.1	14,405	40.9	16,595	42.4	11,616	34.0	29,226	48.5	20,458	39.7
All Other Expense	9,323	42.8	15,480	43.9	17,059	43.6	17,059	49.9	25,158	41.7	25,158	48.8
Total Expense	21,765	100.0	35,260	100.0	39,137	100.0	34,158	100.0	60,318	100.0	51,550	100.0
Effective Gross/ Income*	47,709		64,994		69,566		69,566		93,014		93,014	
Energy/Income Ratio	16.0%		22.2%		23.9%		16.7%		31.5%		22.0%	
Expense/Income Ratio	45.6%		54.3%		56.3%		49.1%		64.8%		55.4%	

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* Gross Possible Income Less Allowance for Vacancy

Energy expense projected at 5% more than all other expenses, or 15.2%.

See report text for assumptions

SOURCE: Real Estate Research Corporation

TABLE A4: PROTOTYPE BUILDING

PROJECTED INCOME AND EXPENSE

BUILDING: LARGE APARTMENT, CLIMATE ZONE 2 (OWNER UTILITIES)

	1975		1980 BASE		1981				1985			
					TREND		RETROFIT		TREND		RETROFIT	
	Money	Percent Expense	Money	Percent Expense	Money	Percent	Money	Percent	Money	Percent	Money	Percent
Real Estate Tax	10,500	9.3	11,375	6.5	11,464	5.8	11,464	6.4	11,826	3.7	11,826	4.1
Energy Expense	28,328	25.1	50,487	28.7	57,555	29.2	40,288	22.3	97,208	30.7	68,046	23.6
All Other Expenses	74,167	65.6	114,013	64.8	128,380	65.0	128,380	71.3	208,105	65.6	208,105	72.3
Total Expense	112,995	100.0	175,875	100.0	197,399	100.0	180,132	100.0	317,139	100.0	287,977	100.0
Effective Gross/ Income*	242,865		342,475		369,991		369,991		504,053		504,053	
Energy/Income Ratio	11.7%		14.7%		15.6%		10.9%		19.3%		13.5%	
Expense/Income Ratio	46.5%		51.4%		53.4%		48.7%		62.9%		57.1%	

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* Gross Possible Income Less Allowance for Vacancy

Energy expense projected at 5% more than all other expenses, or 14%.

See report text for assumptions.

SOURCE: Real Estate Research Corporation

TABLE A5: PROTOTYPE BUILDING

PROJECTED INCOME AND EXPENSE

BUILDING: SMALL APARTMENT, CLIMATE ZONE 4 (TENANT MOST UTILITIES)

	1975		1980 BASE		1981				1985			
					TREND		RETROFIT		TREND		RETROFIT	
	Money	Percent Expense	Money	Percent Expense	Money	Percent	Money	Percent	Money	Percent	Money	Percent
Real Estate Tax	4,290	27.7	6,240	25.0	6,677	24.5	6,677	26.0	8,752	22.4	8,752	23.0
Energy Expense	2,730	17.6	4,875	19.5	5,440	19.9	3,808	14.8	8,439	21.6	5,907	16.2
All Other Expenses	8,465	54.7	13,845	55.5	15,174	55.6	15,174	59.2	21,895	56.0	21,895	59.9
Total Expense	15,485	100.0	24,960	100.0	27,291	100.0	25,659	100.0	39,086	100.0	36,554	100.0
Effective Gross/ Income*	42,783		56,413		60,958		60,958		83,110		83,110	
Energy/Income Ratio	6.4%		8.6%		8.9%		6.2%		10.2%		7.1%	
Expense/Income Ratio	36.0%		44.2%		44.8%		42.1%		47.0%		44.0%	

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* Gross Possible Income Less Allowance for Vacancy

Energy expense projected at 2% more than all other expenses, or 11.6%.

See report text for assumption.

SOURCE: Real Estate Research Corporation

TABLE A6: PROTOTYPE BUILDING

PROJECTED INCOME AND EXPENSE

BUILDING: LARGE APARTMENT, CLIMATE ZONE 4 (TENANT MOST UTILITIES)

	1975		1980 BASE		1981				1985			
					TREND		RETROFIT		TREND		RETROFIT	
	Money	Percent Expense	Money	Percent Expense	Money	Percent	Money	Percent	Money	Percent	Money	Percent
Real Estate Tax	28,322	28.2	39,803	24.4	42,510	23.6	42.510	24.6	55,306	21.1	55,306	22.0
Energy Expense	11,187	11.1	20,667	12.6	23,250	12.9	16,275	9.4	37,243	14.2	26,070	10.4
All Other Expenses	60,865	60.7	103,030	63.0	114,142	63.5	114,142	66.0	170,016	64.7	170,016	67.6
Total Expense	100,374	100.0	163,500	100.0	179,902	100.0	172,927	100.0	262,565	100.0	251,392	100.0
Effective Gross/ Income*	244,178		358,614		390,721		390,721		550,605		550,605	
Energy/Income Ratio	4.6%		5.8%		6.0%		4.2%		6.8%		4.7%	
Expense/Income Ratio	41.0%		45.6%		46.0%		44.3%		47.8%		45.7%	

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* Gross Possible Income Less Allowance for Vacancy

Energy expense projected at 2% more than all other expenses, or 12.5%.

See report text for assumptions.

SOURCE: Real Estate Research Corporation

ENERGY RETROFIT TESTS
SMALL APARTMENT BUILDING
CLIMATE ZONE 1

FUNDAMENTAL PACKAGE

```
CASH FLOW ANALYSIS
=================
                                            1981      1983      1984      1985
 5   NET INCOME                            37821.    43063.    45836.    48691.
11   CASH THROW-OFF                         4550.*    9793.    12565.    15420.
18   SPENDABLE CASH AFTER TAX               6390.*    8149.     9002.     9812.
19   END OF YEAR MARKET VALUE             343794.   391445.   416646.   442601.
32   ORIG EQUITY RTN B/4 TAXES             0.0611*   0.1315    0.1687    0.2071
33   ORIG EQUITY PAYBACK B/4 TAX           0.5129    0.7094    0.8303    0.9621
37   ORIG EQUITY RTN AFT TAX               0.0858*   0.1094    0.1209    0.1318
38   ORIG EQUITY PAYBACK AFT TAX           0.5939    0.7968    0.9176    1.0494
44   MOD. I.R.R. ON ORIG EQUITY           -0.1469   -0.0120    0.0225    0.0462
48   MOD. I.R.R. ON ORIG EQUITY            0.1686    0.1890    0.1900    0.1887
PROGRAM STOP AT 980
```

FUNDAMENTAL PACKAGE PLUS TAX CREDIT

```
CASH FLOW ANALYSIS
=================
                                            1981      1983      1984      1985
 5   NET INCOME                            37821.    43063.    45836.    48691.
11   CASH THROW-OFF                         4550.     9793.    12565.    15420.
18   SPENDABLE CASH AFTER TAX               9456.     7870.     8723.     9533.
19   END OF YEAR MARKET VALUE             343794.   391445.   416646.   442601.
32   ORIG EQUITY RTN B/4 TAXES             0.0611    0.1315    0.1687    0.2071
33   ORIG EQUITY PAYBACK B/4 TAX           0.5129    0.7057    0.8228    0.9508
37   ORIG EQUITY RTN AFT TAX               0.1270    0.1057    0.1171    0.1280
38   ORIG EQUITY PAYBACK AFT TAX           0.6351    0.8305    0.9476    1.0756
44   MOD. I.R.R. ON ORIG EQUITY           -0.1285   -0.0036    0.0284    0.0505
48   MOD. I.R.R. ON ORIG EQUITY            0.1721    0.1909    0.1915    0.1899
PROGRAM STOP AT 980
```

MODIFIED PACKAGE

```
CASH FLOW ANALYSIS
=================
                                            1981      1983      1984      1985
 5   NET INCOME                            37821.    43063.    45836.    48691.
11   CASH THROW-OFF                         7063.    12305.    15077.    17933.
18   SPENDABLE CASH AFTER TAX               8649.    10826.    11949.    13081.
19   END OF YEAR MARKET VALUE             343794.   391445.   416646.   442601.
32   ORIG EQUITY RTN B/4 TAXES             0.0948    0.1652    0.2025    0.2408
33   ORIG EQUITY PAYBACK B/4 TAX           0.5466    0.8129    0.9733    1.1490
37   ORIG EQUITY RTN AFT TAX               0.1161    0.1454    0.1605    0.1756
38   ORIG EQUITY PAYBACK AFT TAX           0.6242    0.8959    1.0564    1.2320
44   MOD. I.R.R. ON ORIG EQUITY           -0.1333    0.0096    0.0445    0.0680
48   MOD. I.R.R. ON ORIG EQUITY            0.1694    0.1901    0.1909    0.1895
```

*IN THESE AND SUBSEQUENT TESTS, THIS ITEM HAS BEEN ADJUSTED IN 1981 TO NET OUT THE ADDITIONAL CASH FLOW CREATED BY THE ENERGY INVESTMENT LOAN.

```
                    P R O   F O R M A
                 INVESTMENT ANALYSIS OF

                 SMALL APT. BDG.CZ1

                              FOR

                 RERC

              SMALL APARTMENT BUILDING
                   CLIMATE ZONE 1
                     BASE CASE

R E P O R T   S E C T I O N   N U M B E R   1          PAGE 1
==================================================

* GROSS RENT      $  84609.  * RATE OF GROWTH OF GROSS RENT  0.0815
* EXPENSES        $  29817.  * RATE OF GROWTH OF EXPENSES    0.1302
* R E TAXES       $  14292.  * RATE OF GROWTH OF R E TAXES   0.0500
  INCOME TAX RATE    0.5000    PROJECT VALUE GROWTH OF       2.0000
* VACANCY RATE       0.0344    WORKING CAPITAL LOAN RATE     0.
  EQUITY DISCOUNT    0.1200    EXTRAORDINARY EXPENSES     $      0.
  RESALE COST        0.0700    REINVESTMENT RATE             0.0850
  WKG CAPITAL RS $        0.   CAPITAL RESER INTEREST RATE   0.
  INITIAL COST $   297883.     INITIAL EQUITY REQUIRED    $  74471.

  ALL '*' VALUES ARE AVERAGE AMOUNTS FOR HOLDING PERIOD. OF  7 YRS.


                    P R O   F O R M A
                 INVESTMENT ANALYSIS OF

                 SMALL APT. BDG.CZ1

                              FOR

                 RERC



R E P O R T   S E C T I O N   N U M B E R   2          PAGE 1
==================================================


            C O M P O N E N T   S U M M A R Y

   TITLE
                       PCT. BEGIN USEFUL  DEPR
                       DEPR  USE   LIFE  METHOD        COST    SCH
SHELL                  0.90   1     30.    2     $   128120.   0
PLUMBING               1.00   1     25.    2     $     3038.   0
HVAC                   1.00   1     15.    2     $    18990.   0
ELECTRIC               1.00   1     20.    2     $    13166.   0
INTERIOR FINISH        0.90   1     15.    2     $    66339.   0
OTHER                  1.00   1     13.    2     $    23548.   0
LAND                   0.     1      0.    0     $    44682.   0

            M O R T G A G E   S U M M A R Y

    TITLE                INTR BEGIN END  TERM        ORIG    PCT
                         RATE  YR.  YR.              BALC   VALUE

FIRST MORTGAGE          0.1125   1    7   25   $   223412. 0.750
```

```
                  P R O   F O R M A
                INVESTMENT ANALYSIS OF

                SMALL APT. BDG.CZ1

                         FOR

                  RERC

               BASE CASE (CONTINUED)


 R E P O R T   S E C T I O N   N U M B E R   3         PAGE 1
 =================================================


 CASH FLOW ANALYSIS
 ==================
                                       1979     1980     1981     1982     1983     1984     1985          0          0          0
  1   GROSS INCOME                   66002.   71578.   77366.   83623.   90387.   97699.  105605.         0.         0.         0.
  2     LESS VACANCY                  2273.    2466.    2664.    2877.    3107.    3355.    3624.         0.         0.         0.
  3     LESS REAL ESTATE TAXES       12289.   12902.   13547.   14224.   14936.   15682.   16467.         0.         0.         0.
  4     LESS EXPENSES                19819.   22964.   25793.   29615.   32590.   36664.   41276.         0.         0.         0.
  5   NET INCOME                     31621.   33246.   35362.   36906.   39754.   41998.   44239.         0.         0.         0.
  6     LESS DEPRECIATION            11681.   11681.   11681.   11681.   11681.   11681.   11681.         0.         0.         0.
  7     LESS INTEREST                25047.   24844.   24617.   24363.   24078.   23760.   23404.         0.         0.         0.
  8   TAXABLE INCOME                 -5107.   -3279.    -936.     863.    3995.    6556.    9153.         0.         0.         0.
  9     PLUS DEPRECIATION            11681.   11681.   11681.   11681.   11681.   11681.   11681.         0.         0.         0.
 10     LESS PRINCIPAL PAYMENTS       1715.    1918.    2146.    2400.    2684.    3002.    3358.         0.         0.         0.
 11   CASH THROW-OFF                  4859.    6484.    8600.   10144.   12992.   15235.   17477.         0.         0.         0.
 12     LESS TAXES                       0.       0.       0.     431.    1997.    3278.    4577.         0.         0.         0.
 13     LESS RESERVES                    0.       0.       0.       0.       0.       0.       0.         0.         0.         0.
 14   CASH FROM OPERATIONS            4859.    6484.    8600.    9713.   10995.   11957.   12900.         0.         0.         0.
 15   WORKING CAPITAL LOAN               0.       0.       0.       0.       0.       0.       0.         0.         0.         0.
 16   DISTRIBUTABLE CASH AFR TAX      4859.    6484.    8600.    9713.   10995.   11957.   12900.         0.         0.         0.
 17   TAX SAVING ON OTHER INCOME      2554.    1640.     468.       0.       0.       0.       0.         0.         0.         0.
 18   SPENDABLE CASH AFTER TAX        7412.    8123.    9068.    9713.   10995.   11957.   12900.         0.         0.         0.

 MARKET VALUE & REVERSION
 ========================

 CASH FLOW ANALYSIS
 ==================
                                       1979     1980     1981     1982     1983     1984     1985          0          0          0
 19   END OF YEAR MARKET VALUE      287435.  302206.  321441.  335480.  361366.  381759.  402133.         0.         0.         0.
 20     LESS RESALE COST             20120.   21154.   22501.   23484.   25296.   26723.   28149.         0.         0.         0.
 21     LESS LOAN BALANCES          221697.  219779.  217633.  215234.  212550.  209547.  206190.         0.         0.         0.
 22     PLUS CUM. CASH RESERVES          0.       0.       0.       0.       0.       0.       0.         0.         0.         0.
 23   B/4 TAX NET WORTH              45617.   61273.   81307.   96763.  123521.  145488.  167794.         0.         0.         0.
 24   CAPITAL GAIN (IF SOLD)        -18887.    6531.   36101.   60838.   96593.  127239.  157868.         0.         0.         0.
 25     CAPITAL GAINS TAX            -4722.    1633.    9025.   15209.   24148.   31810.   39467.         0.         0.         0.
 26     MINIMUM PREF. TAX                0.       0.    1208.    3063.    5745.    8043.   10340.         0.         0.         0.
 27     INCOME TAX ON EXCESS DEP         0.       0.       0.       0.       0.       0.       0.         0.         0.         0.
 28     TOTAL TAX ON SALE            -2361.    1633.   10233.   18272.   29893.   39853.   49807.         0.         0.         0.
 29   AFTER TAX NET WORTH            47978.   59640.   71074.   78490.   93628.  105635.  117986.         0.         0.         0.
```

```
BEFORE TAX RATIO ANALYSIS
========================                                        BASE CASE (CONTINUED)

CASH FLOW ANALYSIS
==================
                                         1979      1980      1981      1982      1983      1984      1985       0         0         0
30   RETURN ON NET WORTH B/4 TAX      -0.3222    0.4053    0.4673    0.3149    0.4108    0.3012    0.2734      0.        0.        0.
31   CHANGE IN NET WORTH B/4 TAX      -28854.    15655.    20034.    15456.    26758.    21967.    22306.      0.        0.        0.
32   ORIG EQUITY RTN B/4 TAXES         0.0652    0.0871    0.1155    0.1362    0.1745    0.2046    0.2347      0.        0.        0.
33   ORIG EQUITY PAYBACK B/4 TAX       0.0652    0.1523    0.2678    0.3982    0.5450    0.7064    0.8796      0.        0.        0.
34   PRESENT VALUE B/4 TAX            268480.   281765.   296913.   306982.   322948.   334287.   344385.      0.        0.        0.

AFTER TAX RATIO ANALYSIS
========================

CASH FLOW ANALYSIS
==================
                                         1979      1980      1981      1982      1983      1984      1985       0         0         0
35   RETURN ON NET WORTH AFT TAX      -0.2562    0.4124    0.3430    0.2410    0.3329    0.2560    0.2390      0.        0.        0.
36   CHANGE IN NET WORTH AFT TAX      -26493.    11662.    12642.     9271.    17820.    14306.    14648.      0.        0.        0.
37   ORIG EQUITY RTN AFT TAX           0.0995    0.1091    0.1218    0.1304    0.1476    0.1606    0.1732      0.        0.        0.
38   ORIG EQUITY PAYBACK AFT TAX       0.0995    0.2086    0.3304    0.4600    0.6084    0.7690    0.9422      0.        0.        0.
39   PRESENT VALUE AFTER TAXES        272868.   284051.   293550.   299015.   308499.   314948.   320636.      0.        0.        0.

CASH FLOW ANALYSIS
==================
                                         1979      1980      1981      1982      1983      1984      1985       0         0         0
40   NET INCOME-MARKET VALUE RTO       0.1100    0.1100    0.1100    0.1100    0.1100    0.1100    0.1100      0.        0.        0.
41   LENDER BONUS INTEREST RATE        0.        0.        0.        0.        0.        0.        0.          0.        0.        0.
42   DEFAULT RATIO                     0.8919    0.8750    0.8544    0.8443    0.8219    0.8097    0.8002      0.        0.        0.

MODIFIED INTERNAL RATE OF RETURN ANALYSIS
=========================================
RETURN ANALYSIS WITHOUT SALE
============================

CASH FLOW ANALYSIS
==================
                                         1979      1980      1981      1982      1983      1984      1985       0         0         0
43   CUM. AFT TAX SPENDABLE CASH        7412.    16165.    26608.    38582.    52856.    69306.    88897.      0.        0.        0.
44   MOD. I.R.R. ON ORIG EQUITY       -0.9005   -0.5341   -0.2904   -0.1516   -0.0553   -0.0119    0.0243      0.        0.        0.
45   MOD. I.R.R. ON CUM. EQUITY       -0.9005   -0.5341   -0.2904   -0.1516   -0.0663   -0.0119    0.0243      0.        0.        0.

RETURN ANALYSIS WITH SALE
=========================

CASH FLOW ANALYSIS
==================
                                         1979      1980      1981      1982      1983      1984      1985       0         0         0
46   CUM. CASH LESS ORIG EQUITY       -21441.     1335.    23211.    42602.    72013.   100470.   131613.      0.        0.        0.
47   CUM. CASH LESS CUM. EQUITY       -21441.     1335.    23211.    42602.    72013.   100470.   131613.      0.        0.        0.
48   MOD. I.R.R. ON ORIG EQUITY       -0.2879    0.0089    0.0947    0.1197    0.1449    0.1530    0.1555      0.        0.        0.
49   MOD. I.R.R. ON CUM. EQUITY       -0.2879    0.0089    0.0947    0.1197    0.1449    0.1530    0.1555      0.        0.        0.
PROGRAM STOP AT 980
```

ENERGY RETROFIT TESTS
LARGE APARTMENT BUILDING
CLIMATE ZONE 1

FUNDAMENTAL PACKAGE

```
 CASH FLOW ANALYSIS
 ==================
                                        1981      1983      1984      1985
  5   NET INCOME                     289224.   325818.   344637.   363592.
 11   CASH THROW-OFF                  24079.    60673.    79492.    98448.
 18   SPENDABLE CASH AFTER TAX        52104.    64796.    70755.    76264.
 19   END OF YEAR MARKET VALUE      2864470.  3226897.  3413285.  3601018.
 32   ORIG EQUITY RTN B/4 TAXES       0.0378    0.0953    0.1248    0.1546
 33   ORIG EQUITY PAYBACK B/4 TAX     0.3046    0.4660    0.5771    0.6959
 37   ORIG EQUITY RTN AFT TAX         0.0818    0.1017    0.1111    0.1198
 38   ORIG EQUITY PAYBACK AFT TAX     0.4545    0.6482    0.7593    0.8791
 44   MOD. I.R.R. ON ORIG EQUITY     -0.2184   -0.0525   -0.0103    0.0188
 48   MOD. I.R.R. ON ORIG EQUITY      0.1213    0.1570    0.1618    0.1632

PROGRAM STOP AT 980
```

FUNDAMENTAL PACKAGE PLUS TAX CREDIT

```
 CASH FLOW ANALYSIS
 ==================
                                        1981      1983      1984      1985
  5   NET INCOME                     289224.   325818.   344637.   363592.
 11   CASH THROW-OFF                  24079.    60673.    79492.    98448.
 18   SPENDABLE CASH AFTER TAX        69205.    63241.    69202.    74709.
 19   END OF YEAR MARKET VALUE      2864470.  3226897.  3413285.  3601018.
 32   ORIG EQUITY RTN B/4 TAXES       0.0378    0.0953    0.1248    0.1546
 33   ORIG EQUITY PAYBACK B/4 TAX     0.3046    0.4660    0.5747    0.6920
 37   ORIG EQUITY RTN AFT TAX         0.1087    0.0993    0.1087    0.1173
 38   ORIG EQUITY PAYBACK AFT TAX     0.4814    0.6702    0.7788    0.8962
 44   MOD. I.R.R. ON ORIG EQUITY     -0.2040   -0.0460   -0.0058    0.0221
 48   MOD. I.R.R. ON ORIG EQUITY      0.1238    0.1584    0.1628    0.1641

PROGRAM STOP AT 980
```

MODIFIED PACKAGE

```
 CASH FLOW ANALYSIS
 ==================
                                        1981      1983      1984      1985
  5   NET INCOME                     289224.   325818.   344637.   363592.
 11   CASH THROW-OFF                  38088.    74682.    93502.   112457.
 18   SPENDABLE CASH AFTER TAX        64688.    79724.    87194.    94490.
 19   END OF YEAR MARKET VALUE      2864470.  3226897.  3413285.  3601018.
 32   ORIG EQUITY RTN B/4 TAXES       0.0378    0.1173    0.1468    0.1766
 33   ORIG EQUITY PAYBACK B/4 TAX     0.3266    0.5320    0.6689    0.8173
 37   ORIG EQUITY RTN AFT TAX         0.1087    0.1252    0.1369    0.1484
 38   ORIG EQUITY PAYBACK AFT TAX     0.4743    0.7128    0.8498    0.9981
 44   MOD. I.R.R. ON ORIG EQUITY     -0.2078   -0.0358    0.0068    0.0357
 48   MOD. I.R.R. ON ORIG EQUITY      0.1219    0.1578    0.1625    0.1639

PROGRAM STOP AT 980
```

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                    P R O   F O R M A
                INVESTMENT ANALYSIS OF

                LARGE APT. BDG.CZ1

                         FOR

                  RERC

              LARGE APARTMENT BUILDING
                   CLIMATE ZONE 1
                     BASE CASE

 R E P O R T   S E C T I O N   N U M B E R    1          PAGE 1
 **************************************************

* GROSS RENT      $ 626439.  * RATE OF GROWTH OF GROSS RENT  0.0025
* EXPENSES        $ 225685.  * RATE OF GROWTH OF EXPENSES    0.1407
* R E TAXES       $  96181.  * RATE OF GROWTH OF R E TAXES   0.0503
  INCOME TAX RATE   0.5000     PROJECT VALUE GROWTH OF       2.0002
* VACANCY RATE      0.0269     WORKING CAPITAL LOAN RATE     0.
  EQUITY DISCOUNT   0.1200     EXTRAORDINARY EXPENSES     $      0.
  RESALE COST       0.0700     REINVESTMENT RATE             0.0850
  WKG CAPITAL RS $      0.     CAPITAL RESER INTEREST RATE   0.
  INITIAL COST $  2547276.     INITIAL EQUITY REQUIRED    $  636819.

  ALL '*' VALUES ARE AVERAGE AMOUNTS FOR HOLDING PERIOD. OF  7 YRS.
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                    P R O   F O R M A
                INVESTMENT ANALYSIS OF

                LARGE APT. BDG.CZ1

                         FOR

                  RERC



 R E P O R T   S E C T I O N   N U M B E R    2          PAGE 1
 **************************************************



              C O M P O N E N T   S U M M A R Y

    TITLE              PCT. BEGIN USEFUL  DEPR
                       DEPR  USE   LIFE  METHOD      COST     SCH
 SHELL                 0.90   1     30.     2    $  1160028.   0
 PLUMBING              1.00   1     25.     2    $    27511.   0
 HVAC                  1.00   1     15.     2    $   171941.   0
 ELECTRIC              1.00   1     20.     2    $   119213.   0
 INTERIOR FINISH       0.90   1     15.     2    $   600648.   0
 OTHER                 1.00   1     13.     2    $   213207.   0
 LAND                  0.     1      0.     0    $   254720.   0

              M O R T G A G E   S U M M A R Y

     TITLE               INTR BEGIN END  TERM        ORIG     PCT
                         RATE  YR.  YR.              BALC    VALUE

 FIRST MORTGAGE        0.1125   1    7    25   $  1910457.  0.750
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                P R O   F O R M A
              INVESTMENT ANALYSIS OF

              LARGE APT. BDG.C21

                         FOR

                RERC

              BASE CASE (CONTINUED)


R E P O R T    S E C T I O N    N U M B E R    3          PAGE 1
=================================================


CASH FLOW ANALYSIS
==================
                                      1979      1980      1981      1982      1983      1984      1985         0         0         0
 1   GROSS INCOME                  487607.   528225.   571662.   618695.   669623.   724771.   784492.        0.        0.        0.
 2     LESS VACANCY                 13245.    14239.    15378.    16608.    17936.    19371.    20921.        0.        0.        0.
 3     LESS REAL ESTATE TAXES       82556.    86845.    91187.    95747.   100534.   105561.   110839.        0.        0.        0.
 4     LESS EXPENSES               145811.   169937.   192838.   218919.   248636.   282511.   321146.        0.        0.        0.
 5   NET INCOME                    245995.   257204.   272260.   287422.   302517.   317328.   331586.        0.        0.        0.
 6     LESS DEPRECIATION           105764.   105764.   105764.   105764.   105764.   105764.   105764.        0.        0.        0.
 7     LESS INTEREST               214185.   212448.   210504.   208330.   205899.   203179.   200138.        0.        0.        0.
 8   TAXABLE INCOME                -73955.   -61008.   -44009.   -26673.    -9146.     8385.    25685.        0.        0.        0.
 9     PLUS DEPRECIATION           105764.   105764.   105764.   105764.   105764.   105764.   105764.        0.        0.        0.
10     LESS PRINCIPAL PAYMENTS      14666.    16403.    18347.    20521.    22952.    25672.    28714.        0.        0.        0.
11   CASH THROW-OFF                 17144.    28353.    43408.    58570.    73665.    88477.   102735.        0.        0.        0.
12     LESS TAXES                       0.        0.        0.        0.        0.     4192.    12842.        0.        0.        0.
13     LESS RESERVES                    0.        0.        0.        0.        0.        0.        0.        0.        0.        0.
14   CASH FROM OPERATIONS           17144.    28353.    43408.    58570.    73665.    84284.    89893.        0.        0.        0.
15   WORKING CAPITAL LOAN               0.        0.        0.        0.        0.        0.        0.        0.        0.        0.
16   DISTRIBUTABLE CASH AFR TAX     17144.    28353.    43408.    58570.    73665.    84284.    89893.        0.        0.        0.
17   TAX SAVING ON OTHER INCOME     36977.    30504.    22004.    13336.     4573.        0.        0.        0.        0.        0.
18   SPENDABLE CASH AFTER TAX       54121.    58857.    65413.    71907.    78238.    84284.    89893.        0.        0.        0.

MARKET VALUE & REVERSION
========================

CASH FLOW ANALYSIS
==================
                                      1979      1980      1981      1982      1983      1984      1985         0         0         0
19   END OF YEAR MARKET VALUE     2436335.  2547348.  2696458.  2846624.  2996124.  3142817.  3284031.        0.        0.        0.
20     LESS RESALE COST            170543.   178314.   188752.   199264.   209729.   219997.   229882.        0.        0.        0.
21     LESS LOAN BALANCES         1895791.  1879388.  1851041.  1840520.  1817567.  1791895.  1763182.        0.        0.        0.
22     PLUS CUM. CASH RESERVES          0.        0.        0.        0.        0.        0.        0.        0.        0.        0.
23   B/4 TAX NET WORTH             370000.   489646.   646666.   806840.   968828.  1130925.  1290967.        0.        0.        0.
24   CAPITAL GAIN (IF SOLD)       -175721.    33286.   277723.   523140.   767939.  1010128.  1247221.        0.        0.        0.
25     CAPITAL GAINS TAX           -43930.     8322.    69431.   130785.   191985.   252532.   311805.        0.        0.        0.
26     MINIMUM PREF. TAX                0.      996.    19329.    37736.    56095.    74260.    92042.        0.        0.        0.
27     INCOME TAX ON EXCESS DEP         0.        0.        0.        0.        0.        0.        0.        0.        0.        0.
28     TOTAL TAX ON SALE           -21965.     9318.    88760.   168521.   248080.   326792.   403847.        0.        0.        0.
29   AFTER TAX NET WORTH           391965.   480328.   557906.   638320.   720747.   804133.   887120.        0.        0.        0.
```

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BEFORE TAX RATIO ANALYSIS
=========================
                                                                     BASE CASE (CONTINUED)
CASH FLOW ANALYSIS
==================
30   RETURN ON NET WORTH B/4 TAX       1979       1980       1981       1982       1983       1984       1985
31   CHANGE IN NET WORTH B/4 TAX    -0.3921     0.4000     0.4093     0.3383     0.2921     0.2586     0.2324   0.        0        0        0
32   ORIG EQUITY RTN B/4 TAXES     -266819.    119646.    157019.    160175.    161987.    162097.    160043.        0.       0.       0.
33   ORIG EQUITY PAYBACK B/4 TAX     0.0269     0.0445     0.0682     0.0920     0.1157     0.1389     0.1613   0.        0.       0.
34   PRESENT VALUE B/4 TAX           0.0269     0.0714     0.1396     0.2316     0.3473     0.4796     0.6208   0.        0.       0.
                                   2256121.   2338710.   2439547.   2529248.   2608025.   2676072.   2733551.   0.        0.       0.
                                                                                                                   0.       0.       0.
AFTER TAX RATIO ANALYSIS
========================

CASH FLOW ANALYSIS
==================
35   RETURN ON NET WORTH AFT TAX       1979       1980       1981       1982       1983       1984       1985
36   CHANGE IN NET WORTH AFT TAX    -0.2995     0.3756     0.2977     0.2730     0.2517     0.2326     0.2150   0.        0        0        0
37   ORIG EQUITY RTN AFT TAX       -244854.     89360.     95910.     98820.    100787.    101550.    100769.        0.       0.       0.
38   ORIG EQUITY PAYBACK AFT TAX     0.0850     0.0924     0.1027     0.1129     0.1229     0.1324     0.1612   0.        0.       0.
39   PRESENT VALUE AFTER TAXES       0.0850     0.1774     0.2801     0.3930     0.5159     0.6483     0.7894   0.        0.       0.
                                   2308748.   2388614.   2449365.   2503621.   2551323.   2592451.   2627004.   0.        0.       0.
CASH FLOW ANALYSIS                                                                                                 0.       0.       0.
==================
40   NET INCOME-MARKET VALUE RTO       1979       1980       1981       1982       1983       1984       1985
41   LENDER BONUS INTEREST RATE      0.1010     0.1010     0.1010     0.1010     0.1010     0.1010     0.1010   0.        0        0        0
42   DEFAULT RATIO                  0.         0.         0.         0.         0.         0.         0.        0.        0.       0.
                                     0.9377     0.9194     0.8972     0.8785     0.8632     0.8512     0.8424   0.        0.       0.
MODIFIED INTERNAL RATE OF RETURN ANALYSIS
=========================================
RETURN ANALYSIS WITHOUT SALE
============================

CASH FLOW ANALYSIS
==================
43   CUM. AFT TAX SPENDABLE CASH       1979       1980       1981       1982       1983       1984       1985
44   MOD. I.R.R. ON ORIG EQUITY      54121.    117578.    192985.    281295.    383444.    500321.    632741.        0        0        0
45   MOD. I.R.R. ON CUM. EQUITY     -0.9150    -0.5703    -0.3283    -0.1848    -0.0965    -0.0394    -0.0009        0.       0.       0.
                                    -0.9150    -0.5703    -0.3283    -0.1848    -0.0965    -0.0394    -0.0009   0.        0.       0.
                                                                                                            0.        0.       0.
RETURN ANALYSIS WITH SALE
=========================

CASH FLOW ANALYSIS
==================
46   CUM. CASH LESS ORIG EQUITY        1979       1980       1981       1982       1983       1984       1985
47   CUM. CASH LESS CUM. EQUITY    -212698.    -38913.    114072.    282796.    467372.    667635.    883042.        0        0        0
48   MOD. I.R.R. ON ORIG EQUITY    -212698.    -38913.    114072.    282796.    467372.    667635.    883042.        0.       0.       0.
49   MOD. I.R.R. ON CUM. EQUITY     -0.3340    -0.0310     0.0565     0.0962     0.1164     0.1269     0.1323        0.       0.       0.
                                    -0.3340    -0.0310     0.0565     0.0962     0.1164     0.1269     0.1323   0.        0.       0.
PROGRAM STOP AT 980                                                                                          0.        0.       0.
```

RERC

ENERGY RETROFIT TESTS
SMALL APARTMENT BUILDING
CLIMATE ZONE 2

FUNDAMENTAL PACKAGE

```
 CASH FLOW ANALYSIS
 ==================
                                          1981       1983       1984       1985
  5   NET INCOME                        35408.     37862.     39692.     41463.
 11   CASH THROW-OFF                      874 .     3329.      5159.      6929.
 18   SPENDABLE CASH AFTER TAX           3760 .     3818.      4003.      4041.
 19   END OF YEAR MARKET VALUE         323099.    345495.    362193.    378349.
 32   ORIG EQUITY RTN B/4 TAXES         0.0129     0.0491     0.0761     0.1022
 33   ORIG EQUITY PAYBACK B/4 TAX       0.6839     0.7647     0.8237     0.8833
 37   ORIG EQUITY RTN AFT TAX           0.0554     0.0563     0.0590     0.0596
 38   ORIG EQUITY PAYBACK AFT TAX       0.7800     0.8931     0.9522     1.0117
 44   MOD. I.R.R. ON ORIG EQUITY       -0.0687     0.0134     0.0335     0.0473
 48   MOD. I.R.R. ON ORIG EQUITY        0.2067     0.1863     0.1834     0.1796

PROGRAM STOP AT 980
```

FUNDAMENTAL PACKAGE PLUS TAX CREDIT

```
 CASH FLOW ANALYSIS
 ==================
                                          1981       1983       1984       1985
  5   NET INCOME                        35408.     37862.     39692.     41463.
 11   CASH THROW-OFF                      874.      3329.      5159.      6929.
 18   SPENDABLE CASH AFTER TAX           8546.      3382.      3568.      3606.
 19   END OF YEAR MARKET VALUE         323099.    345495.    362193.    378349.
 32   ORIG EQUITY RTN B/4 TAXES         0.0129     0.0491     0.0761     0.1022
 33   ORIG EQUITY PAYBACK B/4 TAX       0.6839     0.7647     0.8173     0.8705
 37   ORIG EQUITY RTN AFT TAX           0.1260     0.0499     0.0526     0.0532
 38   ORIG EQUITY PAYBACK AFT TAX       0.8505     0.9509     1.0035     1.0565
 44   MOD. I.R.R. ON ORIG EQUITY       -0.0423     0.0263     0.0431     0.0546
 48   MOD. I.R.R. ON ORIG EQUITY        0.2124     0.1895     0.1860     0.1816

PROGRAM STOP AT 980
```

MODIFIED PACKAGE

```
 CASH FLOW ANALYSIS
 ==================
                                          1981       1983       1984       1985
  5   NET INCOME                        35408.     37862.     39692.     41453.
 11   CASH THROW-OFF                     4795.      7250.      9080.     10850.
 18   SPENDABLE CASH AFTER TAX           7282.      7996.      8603.      9142.
 19   END OF YEAR MARKET VALUE         323099.    345495.    362193.    378349.
 32   ORIG EQUITY RTN B/4 TAXES         0.0707     0.1069     0.1339     0.1600
 33   ORIG EQUITY PAYBACK B/4 TAX       0.7417     0.9381     1.0650     1.1997
 37   ORIG EQUITY RTN AFT TAX           0.1074     0.1179     0.1268     0.1348
 38   ORIG EQUITY PAYBACK AFT TAX       0.8319     1.0630     1.1898     1.3246
 44   MOD. I.R.R. ON ORIG EQUITY       -0.0491     0.0461     0.0683     0.0830
 48   MOD. I.R.R. ON ORIG EQUITY        0.2081     0.1881     0.1851     0.1811

PROGRAM STOP AT 980
```

```
                    P R O   F O R M A
                 INVESTMENT ANALYSIS OF

                 SMALL APT. BDG.CZ2

                          FOR

                 RERC

              SMALL APARTMENT BUILDING
                  CLIMATE ZONE 2
                     BASE CASE

R E P O R T   S E C T I O N   N U M B E R   1         PAGE 1
=====================================================

* GROSS RENT      $  82938.  * RATE OF GROWTH OF GROSS RENT  0.0733
* EXPENSES        $  38946.  * RATE OF GROWTH OF EXPENSES    0.1321
* R E TAXES       $   5596.  * RATE OF GROWTH OF R E TAXES   0.0201
  INCOME TAX RATE    0.5000    PROJECT VALUE GROWTH OF       2.0000
* VACANCY RATE       0.0894    WORKING CAPITAL LOAN RATE     0.
  EQUITY DISCOUNT    0.1200    EXTRAORDINARY EXPENSES     $      0.
  RESALE COST        0.0700    REINVESTMENT RATE             0.0850
  WKG CAPITAL RS $       0.    CAPITAL RESER INTEREST RATE   0.
  INITIAL COST $   271320.     INITIAL EQUITY REQUIRED    $  67830.

  ALL '*' VALUES ARE AVERAGE AMOUNTS FOR HOLDING PERIOD. OF  7 YRS.


                    P R O   F O R M A
                 INVESTMENT ANALYSIS OF

                 SMALL APT. BDG.CZ2

                          FOR

                 RERC


R E P O R T   S E C T I O N   N U M B E R   2         PAGE 1
=====================================================


              C O M P O N E N T   S U M M A R Y

    TITLE                PCT. BEGIN USEFUL  DEPR
                         DEPR  USE   LIFE  METHOD        COST   SCH
SHELL                    0.90   1     30.    2    $   116695.  0
PLUMBING                 1.00   1     25.    2    $     2767.  0
HVAC                     1.00   1     15.    2    $    17297.  0
ELECTRIC                 1.00   1     20.    2    $    11992.  0
INTERIOR FINISH          0.92   1     15.    2    $    60423.  0
OTHER                    1.00   1     13.    2    $    21448.  0
LAND                     0.     1      0.    0    $    40598.  0


               M O R T G A G E   S U M M A R Y

     TITLE                INTR BEGIN END  TERM          ORIG    PCT
                          RATE  YR.  YR.                BALC   VALUE

FIRST MORTGAGE          0.1125   1    7    25   $   203490. 0.750
```

```
                    P R O   F O R M A
                 INVESTMENT ANALYSIS OF

                 SMALL APT. BDG.CZ2

                         FOR

                 RERC

              BASE CASE (CONTINUED)


     R E P O R T   S E C T I O N   N U M B E R   3          PAGE 1
     ==============================================

     CASH FLOW ANALYSIS
     ==================
                                            1979     1980     1981     1982     1983     1984     1985       0        0        0
      1   GROSS INCOME                    66811.   71300.   76398.   81770.   87521.   94547.  102138.      0.       0.       0.
      2     LESS VACANCY                   5979.    6386.    6832.    7311.    7823.    8448.    9124.      0.       0.       0.
      3     LESS REAL ESTATE TAXES         5268.    5375.    5483.    5592.    5704.    5818.    5934.      0.       0.       0.
      4     LESS EXPENSES                 25842.   29805.   33654.   37916.   42739.   48199.   54384.      0.       0.       0.
      5   NET INCOME                      29722.   29735.   30429.   30951.   31255.   32081.   32695.      0.       0.       0.
      6     LESS DEPRECIATION             10639.   10639.   10639.   10639.   10639.   10639.   10639.      0.       0.       0.
      7     LESS INTEREST                 22814.   22629.   22422.   22190.   21931.   21641.   21317.      0.       0.       0.
      8   TAXABLE INCOME                  -3731.   -3534.   -2632.   -1878.   -1315.    -200.     738.      0.       0.       0.
      9     PLUS DEPRECIATION             10639.   10639.   10639.   10639.   10639.   10639.   10639.      0.       0.       0.
     10     LESS PRINCIPAL PAYMENTS        1562.    1747.    1954.    2186.    2445.    2734.    3058.      0.       0.       0.
     11   CASH THROW-OFF                   5346.    5359.    6053.    6575.    6880.    7706.    8319.      0.       0.       0.
     12     LESS TAXES                        0.       0.       0.       0.       0.       0.       0.      0.       0.       0.
     13     LESS RESERVES                     0.       0.       0.       0.       0.       0.     369.      0.       0.       0.
     14   CASH FROM OPERATIONS             5346.    5359.    6053.    6575.    6880.    7706.    7950.      0.       0.       0.
     15   WORKING CAPITAL LOAN                0.       0.       0.       0.       0.       0.       0.      0.       0.       0.
     16   DISTRIBUTABLE CASH AFR TAX       5346.    5359.    6053.    6575.    6880.    7706.    7950.      0.       0.       0.
     17   TAX SAVING ON OTHER INCOME       1866.    1767.    1316.     939.     658.     100.       0.      0.       0.       0.
     18   SPENDABLE CASH AFTER TAX         7212.    7125.    7369.    7515.    7537.    7805.    7950.      0.       0.       0.

     MARKET VALUE & REVERSION
     ========================

     CASH FLOW ANALYSIS
     ==================
                                            1979     1980     1981     1982     1983     1984     1985       0        0        0
     19   END OF YEAR MARKET VALUE       271212.  271327.  277666.  282429.  285206.  292743.  298341.      0.       0.       0.
     20     LESS RESALE COST              18985.   18993.   19437.   19770.   19964.   20492.   20884.      0.       0.       0.
     21     LESS LOAN BALANCES           201928.  200181.  198226.  196041.  193596.  190862.  187803.      0.       0.       0.
     22     PLUS CUM. CASH RESERVES           0.       0.       0.       0.       0.       0.       0.      0.       0.       0.
     23   B/4 TAX NET WORTH               50299.   52154.   60003.   66618.   71645.   81389.   89654.      0.       0.       0.
     24   CAPITAL GAIN (IF SOLD)          -8453.    2293.   18828.   33897.   47119.   64767.   88614.      0.       0.       0.
     25     CAPITAL GAINS TAX             -2113.     573.    4707.    8474.   11780.   16192.   20153.      0.       0.       0.
     26     MINIMUM PREF. TAX                 0.       0.       0.    1042.    2034.    3358.    4546.      0.       0.       0.
     27     INCOME TAX ON EXCESS DEP          0.       0.       0.       0.       0.       0.       0.      0.       0.       0.
     28     TOTAL TAX ON SALE             -1057.     573.    4707.    9517.   13814.   19549.   24700.      0.       0.       0.
     29   AFTER TAX NET WORTH             51356.   51580.   55296.   57102.   57832.   61840.   64955.      0.       0.       0.
```

```
BEFORE TAX RATIO ANALYSIS                                  BASE CASE (CONTINUED)
=========================

CASH FLOW ANALYSIS
==================
                                      1979      1980      1981      1982      1983      1984      1985      0       0       0
30  RETURN ON NET WORTH B/4 TAX    -0.1796    0.1434    0.2666    0.2198    0.1787    0.2436    0.2038   0.      0.      0.
31  CHANGE IN NET WORTH B/4 TAX    -17531.     1855.     7849.     6616.     5027.     9744.     8265.      0.      0.      0.
32  ORIG EQUITY RTN B/4 TAXES       0.0788    0.0790    0.0892    0.0969    0.1014    0.1136    0.1226   0.      0.      0.
33  ORIG EQUITY PAYBACK B/4 TAX     0.0788    0.1578    0.2471    0.3440    0.4454    0.5598    0.6762   0.      0.      0.
34  PRESENT VALUE B/4 TAX          253173.   254112.   259552.   263350.   265580.   270054.   273148.      0.      0.      0.

AFTER TAX RATIO ANALYSIS
========================

CASH FLOW ANALYSIS
==================
                                      1979      1980      1981      1982      1983      1984      1985      0       0       0
35  RETURN ON NET WORTH AFT TAX    -0.1366    0.1431    0.2149    0.1686    0.1448    0.2043    0.1789   0.      0.      0.
36  CHANGE IN NET WORTH AFT TAX    -16474.      225.     3715.     2848.     1722.     5332.     4304.      0.      0.      0.
37  ORIG EQUITY RTN AFT TAX        -0.1063    0.1050    0.1086    0.1108    0.1111    0.1151    0.1172   0.      0.      0.
38  ORIG EQUITY PAYBACK AFT TAX     0.1063    0.2114    0.3200    0.4308    0.5419    0.6570    0.7742   0.      0.      0.
39  PRESENT VALUE AFTER TAXES      255782.   256729.   260213.   261920.   262722.   265191.   265840.      0.      0.      0.
CASH FLOW ANALYSIS
==================
                                      1979      1980      1981      1982      1983      1984      1985      0       0       0
40  NET INCOME-MARKET VALUE RTO     0.1096    0.1096    0.1096    0.1096    0.1096    0.1096    0.1096   0.      0.      0.
41  LENDER BONUS INTEREST RATE      0.        0.        0.        0.        0.        0.        0.       0.      0.      0.
42  DEFAULT RATIO                   0.8305    0.8355    0.8313    0.8302    0.8320    0.8291    0.8292   0.      0.      0.

MODIFIED INTERNAL RATE OF RETURN ANALYSIS
=========================================
RETURN ANALYSIS WITHOUT SALE
============================

CASH FLOW ANALYSIS
==================
                                      1979      1980      1981      1982      1983      1984      1985      0       0       0
43  CUM. AFT TAX SPENDABLE CASH      7212.    14950.    23590.    33110.    43461.    54961.    67593.      0.      0.      0.
44  MOD. I.R.R. ON ORIG EQUITY     -0.8937   -0.5305   -0.2968   -0.1641   -0.0852   -0.0345   -0.0085   0.      0.      0.
45  MOD. I.R.R. ON CUM. EQUITY     -0.8937   -0.5305   -0.2968   -0.1641   -0.0852   -0.0345   -0.0085   0.      0.      0.

RETURN ANALYSIS WITH SALE
=========================

CASH FLOW ANALYSIS
==================
                                      1979      1980      1981      1982      1983      1984      1985      0       0       0
46  CUM. CASH LESS ORIG EQUITY     -10319.    -1299.    11056.    22382.    33463.    48971.    64708.      0.      0.      0.
47  CUM. CASH LESS CUM. EQUITY     -10319.    -1299.    11056.    22382.    33463.    48971.    64708.      0.      0.      0.
48  MOD. I.R.R. ON ORIG EQUITY     -0.1521   -0.0096    0.0516    0.0739    0.0835    0.0948    0.1004   0.      0.      0.
49  MOD. I.R.R. ON CUM. EQUITY     -0.1521   -0.0096    0.0516    0.0739    0.0835    0.0948    0.1004   0.      0.      0.
PROGRAM STOP AT 980
```

ENERGY RETROFIT TESTS
LARGE APARTMENT BUILDING
CLIMATE ZONE 2

FUNDAMENTAL PACKAGE

```
 CASH FLOW ANALYSIS
 ==================
                                        1981       1983       1984       1985
  5   NET INCOME                     189859.    204379.    210687.    216076.
 11   CASH THROW-OFF                  31401.     45921.     52228.     57618.
 18   SPENDABLE CASH AFTER TAX        37922.     41353.     42140.     42103.
 19   END OF YEAR MARKET VALUE      1663168.   1790363.   1845621.   1892828.
 32   ORIG EQUITY RTN B/4 TAXES       0.0862     0.1261     0.1434     0.1582
 33   ORIG EQUITY PAYBACK B/4 TAX     0.5247     0.7451     0.8608     0.9765
 37   ORIG EQUITY RTN AFT TAX         0.1041     0.1136     0.1157     0.1156
 38   ORIG EQUITY PAYBACK AFT TAX     0.5949     0.8181     0.9338     1.0494
 44   MOD. I.R.R. ON ORIG EQUITY     -0.1451    -0.0065     0.0259     0.0472
 48   MOD. I.R.R. ON ORIG EQUITY      0.1614     0.1675     0.1651     0.1614
```

FUNDAMENTAL PACKAGE PLUS TAX CREDIT

```
 CASH FLOW ANALYSIS
 ==================
                                        1981       1983       1984       1985
  5   NET INCOME                     189859.    204379.    210687.    216076.
 11   CASH THROW-OFF                  31401.     45921.     52228.     57618.
 18   SPENDABLE CASH AFTER TAX        50927.     40171.     40958.     40920.
 19   END OF YEAR MARKET VALUE      1663168.   1790363.   1845621.   1892828.
 32   ORIG EQUITY RTN B/4 TAXES       0.0862     0.1261     0.1434     0.1582
 33   ORIG EQUITY PAYBACK B/4 TAX     0.5247     0.7413     0.8538     0.9562
 37   ORIG EQUITY RTN AFT TAX         0.1399     0.1103     0.1125     0.1124
 38   ORIG EQUITY PAYBACK AFT TAX     0.6306     0.8473     0.9598     1.0722
 44   MOD. I.R.R. ON ORIG EQUITY     -0.1291     0.0007     0.0310     0.0509
 48   MOD. I.R.R. ON ORIG EQUITY      0.1644     0.1692     0.1655     0.1626
```

MODIFIED PACKAGE

```
 CASH FLOW ANALYSIS
 ==================
                                        1981       1983       1984       1985
  5   NET INCOME                     189859.    204379.    210687.    216076.
 11   CASH THROW-OFF                  42055.     56575.     62883.     68272.
 18   SPENDABLE CASH AFTER TAX        47492.     52707.     54642.     55964.
 19   END OF YEAR MARKET VALUE      1663168.   1790363.   1845621.   1892828.
 32   ORIG EQUITY RTN B/4 TAXES       0. 1155    0.1554     0.1727     0.1875
 33   ORIG EQUITY PAYBACK B/4 TAX     0.5539     0.8348     0.9849     1.1386
 37   ORIG EQUITY RTN AFT TAX         0.1304     0.1447     0.1501     0.1537
 38   ORIG EQUITY PAYBACK AFT TAX     0.6212     0.9041     1.0541     1.2078
 44   MOD. I.R.R. ON ORIG EQUITY     -0.1332     0.0119     0.0449     0.0651
 48   MOD. I.R.R. ON ORIG EQUITY      0.1621     0.1684     0.1660     0.1623
PROGRAM STOP AT 980
```

```
                    P R O   F O R M A
                 INVESTMENT ANALYSIS OF

                 LARGE APT. BDG.CZ2

                          FOR

                 RERC

              LARGE APARTMENT BUILDING
                   CLIMATE ZONE 2
                     BASE CASE

R E P O R T   S E C T I O N   N U M B E R   1          PAGE 1
==============================================

* GROSS RENT     $ 439170.  * RATE OF GROWTH OF GROSS RENT  0.0805
* EXPENSES       $ 217043.  * RATE OF GROWTH OF EXPENSES    0.1320
* R E TAXES      $  11567.  * RATE OF GROWTH OF R E TAXES   0.0065
  INCOME TAX RATE  0.5000     PROJECT VALUE GROWTH OF       2.0000
* VACANCY RATE     0.0790     WORKING CAPITAL LOAN RATE     0.
  EQUITY DISCOUNT  0.1200     EXTRAORDINARY EXPENSES     $      0.
  RESALE COST      0.0700     REINVESTMENT RATE               0.0850
  WKG CAPITAL RS $       0.   CAPITAL RESER INTEREST RATE   0.
  INITIAL COST $  1456525.    INITIAL EQUITY REQUIRED    $  364131.

  ALL '*' VALUES ARE AVERAGE AMOUNTS FOR HOLDING PERIOD. OF  7 YRS.
```

```
                    P R O   F O R M A
                 INVESTMENT ANALYSIS OF

                 LARGE APT. BDG.CZ2

                          FOR

                 RERC



R E P O R T   S E C T I O N   N U M B E R   2          PAGE 1
==============================================



              C O M P O N E N T   S U M M A R Y

   TITLE               PCT. BEGIN USEFUL  DEPR
                       DEPR   USE   LIFE  METHOD       COST    SCH
SHELL                  0.90    1     30.     2    $   563303.   0
PLUMBING               1.00    1     25.     2    $    15730.   0
HVAC                   1.00    1     15.     2    $    98315.   0
ELECTRIC               1.00    1     20.     2    $    58165.   0
INTERIOR FINISH        0.90    1     15.     2    $   343449.   0
OTHER                  1.00    1     13.     2    $   121911.   0
LAND                   0.      1      0.     0    $   145652.   0


              M O R T G A G E   S U M M A R Y

    TITLE               INTR BEGIN END  TERM          ORIG    PCT
                        RATE  YR.  YR.                BALC   VALUE

FIRST MORTGAGE        0.1125   1    7    25   $  1092394. 0.750
```

```
                    P R O   F O R M A
              INVESTMENT ANALYSIS OF

              LARGE APT. BDG.CZ2

                         FOR

              RERC

                    BASE CASE (CONTINUED)


REPORT  SECTION  NUMBER   3          PAGE 1
================================================


CASH FLOW ANALYSIS
==================
                                       1979      1980      1981      1982      1983      1984      1985         0         0         0
 1  GROSS INCOME                    343875.   371075.   401743.   434013.   468879.   506558.   547251.        0.        0.        0.
 2    LESS VACANCY                   27230.    29400.    31752.    34292.    37036.    39998.    43198.        0.        0.        0.
 3    LESS REAL ESTATE TAXES         11375.    11375.    11464.    11553.    11643.    11734.    11826.        0.        0.        0.
 4    LESS EXPENSES                 145100.   164500.   185935.   210478.   238261.   269711.   305313.        0.        0.        0.
 5  NET INCOME                      160170.   166500.   172592.   177690.   181939.   185106.   186914.        0.        0.        0.
 6    LESS DEPRECIATION              60476.    60476.    60476.    60476.    60476.    60476.    60476.        0.        0.        0.
 7    LESS INTEREST                 122471.   121477.   120366.   119123.   117732.   116177.   114430.        0.        0.        0.
 8  TAXABLE INCOME                  -22776.   -15353.    -8249.    -1908.     3731.     8453.    12001.        0.        0.        0.
 9    PLUS DEPRECIATION              60476.    60476.    60476.    60476.    60476.    60476.    60476.        0.        0.        0.
10    LESS PRINCIPAL PAYMENTS         8386.     9379.    10491.    11734.    13124.    14679.    16418.        0.        0.        0.
11  CASH THROW-OFF                   29314.    35744.    41735.    46834.    51083.    54250.    56058.        0.        0.        0.
12    LESS TAXES                         0.        0.        0.        0.     1866.     4227.     6008.        0.        0.        0.
13    LESS RESERVES                      0.        0.        0.        0.        0.        0.        0.        0.        0.        0.
14  CASH FROM OPERATIONS             29314.    35744.    41736.    46834.    49217.    50023.    50057.        0.        0.        0.
15  WORKING CAPITAL LOAN                 0.        0.        0.        0.        0.        0.        0.        0.        0.        0.
16  DISTRIBUTABLE CASH AFR TAX       29314.    35744.    41736.    46834.    49217.    50023.    50057.        0.        0.        0.
17  TAX SAVING ON OTHER INCOME       11388.     7676.     4124.      954.        0.        0.        0.        0.        0.        0.
18  SPENDABLE CASH AFTER TAX         40702.    43420.    45860.    47788.    49217.    50023.    50057.        0.        0.        0.

MARKET VALUE & REVERSION
========================

CASH FLOW ANALYSIS
==================
                                       1979      1980      1981      1982      1983      1984      1985         0         0         0
19  END OF YEAR MARKET VALUE       1403089.  1459416.  1511909.  1556565.  1593789.  1621531.  1637369.        0.        0.        0.
20    LESS RESALE COST               98216.   102159.   105834.   108950.   111565.   113507.   114616.        0.        0.        0.
21    LESS LOAN BALANCES           1084008.  1074628.  1064138.  1052404.  1039288.  1024601.  1008182.        0.        0.        0.
22    PLUS CUM. CASH RESERVES            0.        0.        0.        0.        0.        0.        0.        0.        0.        0.
23  B/4 TAX NET WORTH               220865.   282620.   341938.   395201.   442944.   483423.   514571.        0.        0.        0.
24  CAPITAL GAIN (IF SOLD)          -91176.    21683.   130978.   212983.   328077.   414352.   489557.        0.        0.        0.
25    CAPITAL GAINS TAX             -22794.     5421.    32744.    58246.    82019.   103588.   122189.        0.        0.        0.
26    MINIMUM PREF. TAX                  0.      126.     8323.    15974.    23106.    29576.    35217.        0.        0.        0.
27    INCOME TAX ON EXCESS DEP           0.        0.        0.        0.        0.        0.        0.        0.        0.        0.
28    TOTAL TAX ON SALE             -11397.     5547.    41068.    74219.   105125.   133165.   157606.        0.        0.        0.
29  AFTER TAX NET WORTH             232262.   277081.   300870.   320982.   337819.   350259.   356965.        0.        0.        0.
```

```
BEFORE TAX RATIO ANALYSIS                                  BASE CASE (CONTINUED)
=========================

CASH FLOW ANALYSIS
==================
                                           1979      1980      1981      1982      1983      1984      1985         0         0         0
30   RETURN ON NET WORTH B/4 TAX        -0.3129    0.4415    0.3575    0.2927    0.2501    0.2139    0.1804    0.        0.        0.
31   CHANGE IN NET WORTH B/4 TAX       -143266.    61763.    59310.    53263.    47743.    40479.    31148.        0.        0.        0.
32   ORIG EQUITY RTN B/4 TAXES           0.0805    0.0982    0.1146    0.1286    0.1403    0.1490    0.1539    0.        0.        0.
33   ORIG EQUITY PAYBACK B/4 TAX         0.0805    0.1787    0.2933    0.4219    0.5571    0.6944    0.8319    0.        0.        0.
34   PRESENT VALUE B/4 TAX             1315767.  1372371.  1420153.  1457689.  1486855.  1507919.  1521125.        0.        0.        0.

AFTER TAX RATIO ANALYSIS
========================

CASH FLOW ANALYSIS
==================
                                           1979      1980      1981      1982      1983      1984      1985         0         0         0
35   RETURN ON NET WORTH AFT TAX        -0.2504    0.3799    0.2514    0.2257    0.2058    0.1849    0.1621    0.        0.        0.
36   CHANGE IN NET WORTH AFT TAX       -131869.    44946.    31986.    27762.    23969.    18910.    12346.        0.        0.        0.
37   ORIG EQUITY RTN AFT TAX             0.1118    0.1192    0.1259    0.1312    0.1352    0.1374    0.1375    0.        0.        0.
38   ORIG EQUITY PAYBACK AFT TAX         0.1118    0.2310    0.3570    0.4882    0.6234    0.7607    0.8982    0.        0.        0.
39   PRESENT VALUE AFTER TAXES         1336111.  1384236.  1410145.  1430351.  1445976.  1457083.  1463748.        0.        0.        0.
CASH FLOW ANALYSIS
==================
                                           1979      1980      1981      1982      1983      1984      1985         0         0         0
40   NET INCOME-MARKET VALUE RTO         0.1142    0.1142    0.1142    0.1142    0.1142    0.1142    0.1142    0.        0.        0.
41   LENDER BONUS INTEREST RATE          0.        0.        0.        0.        0.        0.        0.        0.        0.        0.
42   DEFAULT RATIO                       0.8356    0.8240    0.8171    0.8131    0.8121    0.8139    0.8186    0.        0.        0.

MODIFIED INTERNAL RATE OF RETURN ANALYSIS
=========================================
RETURN ANALYSIS WITHOUT SALE
============================

CASH FLOW ANALYSIS
==================
                                           1979      1980      1981      1982      1983      1984      1985         0         0         0
43   CUM. AFT TAX SPENDABLE CASH         40702.    87581.   140886.   200649.   266921.   339632.   410559.        0.        0.        0.
44   MOD. I.R.R. ON ORIG EQUITY         -0.8882   -0.5096   -0.2713   -0.1384   -0.0602   -0.0115    0.0201    0.        0.        0.
45   MOD. I.R.R. ON CUM. EQUITY         -0.8882   -0.5096   -0.2713   -0.1384   -0.0602   -0.0115    0.0201    0.        0.        0.

RETURN ANALYSIS WITH SALE
=========================

CASH FLOW ANALYSIS
==================
                                           1979      1980      1981      1982      1983      1984      1985         0         0         0
46   CUM. CASH LESS ORIG EQUITY        -102555.      531.    77625.   157500.   240609.   325760.   411392.        0.        0.        0.
47   CUM. CASH LESS CUM. EQUITY        -102565.      531.    77625.   157500.   240609.   325760.   411392.        0.        0.        0.
48   MOD. I.R.R. ON ORIG EQUITY         -0.2817    0.0007    0.0665    0.0940    0.1068    0.1124    0.1141    0.        0.        0.
49   MOD. I.R.R. ON CUM. EQUITY         -0.2817    0.0007    0.0665    0.0940    0.1068    0.1124    0.1141    0.        0.        0.
PROGRAM STOP AT 980
```

ENERGY RETROFIT TESTS
SMALL APARTMENT BUILDING
CLIMATE ZONE 4

FUNDAMENTAL PACKAGE

```
   CASH FLOW ANALYSIS
   ==================
                                           1981      1983      1984      1985
    5   NET INCOME                        35299.    40562.    43462.    46556.
   11   CASH THROW-OFF                      550.     5813.     8714.    11808.
   18   SPENDABLE CASH AFTER TAX           5174.     7080.     8085.     9119.
   19   END OF YEAR MARKET VALUE         375581.   431577.   462438.   495359.
   32   ORIG EQUITY RTN B/4 TAXES         0.0066    0.0694    0.1040    0.1409
   33   ORIG EQUITY PAYBACK B/4 TAX       0.2266    0.3329    0.4294    0.5382
   37   ORIG EQUITY RTN AFT TAX           0.0618    0.0845    0.0965    0.1088
   38   ORIG EQUITY PAYBACK AFT TAX       0.3991    0.5565    0.6530    0.7618
   44   MOD. I.R.R. ON ORIG EQUITY       -0.2520   -0.0808   -0.0348   -0.0020
   48   MOD. I.R.R. ON ORIG EQUITY        0.1103    0.1544    0.1620    0.1657

 PROGRAM STOP AT 980
```

FUNDAMENTAL PACKAGE PLUS TAX CREDIT

```
   CASH FLOW ANALYSIS
   ==================
                                           1981      1983      1984      1985
    5   NET INCOME                        35299.    40562.    43462.    46556.
   11   CASH THROW-OFF                      550.     5813.     8714.    11808.
   18   SPENDABLE CASH AFTER TAX           7359.     6882.     7886.     8920.
   19   END OF YEAR MARKET VALUE         375581.   431577.   462438.   495359.
   32   ORIG EQUITY RTN B/4 TAXES         0.0066    0.0694    0.1040    0.1409
   33   ORIG EQUITY PAYBACK B/4 TAX       0.2266    0.3329    0.4270    0.5335
   37   ORIG EQUITY RTN AFT TAX           0.0878    0.0821    0.0941    0.1065
   38   ORIG EQUITY PAYBACK AFT TAX       0.4252    0.5778    0.6719    0.7784
   44   MOD. I.R.R. ON ORIG EQUITY       -0.2368   -0.0737   -0.0298    0.0016
   48   MOD. I.R.R. ON ORIG EQUITY        0.1127    0.1558    0.1630    0.1665

 PROGRAM STOP AT 980
```

MODIFIED PACKAGE

```
   CASH FLOW ANALYSIS
   ==================
                                           1981      1983      1984      1985
    5   NET INCOME                        35299.    40562.    43462.    46556.
   11   CASH THROW-OFF                     2341.     7603.    10504.    13598.
   18   SPENDABLE CASH AFTER TAX           6782.     8988.    10185.    11448.
   19   END OF YEAR MARKET VALUE         375581.   431577.   462438.   495359.
   32   ORIG EQUITY RTN B/4 TAXES         0.0279    0.0907    0.1254    0.1623
   33   ORIG EQUITY PAYBACK B/4 TAX       0.2480    0.3970    0.5186    0.6552
   37   ORIG EQUITY RTN AFT TAX           0.0809    0.1073    0.1216    0.1366
   38   ORIG EQUITY PAYBACK AFT TAX       0.4183    0.6193    0.7408    0.8775
   44   MOD. I.R.R. ON ORIG EQUITY       -0.2408   -0.0625   -0.0161    0.0165
   48   MOD. I.R.R. ON ORIG EQUITY        0.1109    0.1552    0.1627    0.1653

 PROGRAM STOP AT 980
```

```
                           P R O   F O R M A
                        INVESTMENT ANALYSIS OF

                        SMALL APT. BDG.CZ4

                                  FOR

                          RERC

                      SMALL APARTMENT BUILDING
                           CLIMATE ZONE 4
                             BASE CASE

  R E P O R T   S E C T I O N   N U M B E R   1            PAGE 1
  ================================================

* GROSS RENT     $  68881.  * RATE OF GROWTH OF GROSS RENT  0.0757
* EXPENSES       $  23062.  * RATE OF GROWTH OF EXPENSES    0.1066
* R E TAXES      $   7212.  * RATE OF GROWTH OF R E TAXES   0.0694
  INCOME TAX RATE   0.5000    PROJECT VALUE GROWTH OF       2.0000
* VACANCY RATE      0.0291    WORKING CAPITAL LOAN RATE     0.
  EQUITY DISCOUNT   0.1200    EXTRAORDINARY EXPENSES     $      0.
  RESALE COST       0.0700    REINVESTMENT RATE             0.0850
  WKG CAPITAL RS $      0.    CAPITAL RESER INTEREST RATE   0.
  INITIAL COST $   335155.    INITIAL EQUITY REQUIRED    $  83789.

  ALL '*' VALUES ARE AVERAGE AMOUNTS FOR HOLDING PERIOD. OF  7 YRS.


                           P R O   F O R M A
                        INVESTMENT ANALYSIS OF

                        SMALL APT. BDG.CZ4

                                  FOR

                          RERC


  R E P O R T   S E C T I O N   N U M B E R   2            PAGE 1
  ================================================


               C O M P O N E N T   S U M M A R Y

     TITLE
                         PCT. BEGIN USEFUL  DEPR
                         DEPR  USE   LIFE  METHOD        COST    SCH
  SHELL                  0.90   1     30.     2     $  144150.   0
  PLUMBING               1.00   1     25.     2     $    3419.   0
  HVAC                   1.00   1     15.     2     $   21366.   0
  ELECTRIC               1.00   1     20.     2     $   14814.   0
  INTERIOR FINISH        0.90   1     15.     2     $   74639.   0
  OTHER                  1.00   1     13.     2     $   26494.   0
  LAND                   0.     1      0.     0     $   50273.   0

               M O R T G A G E   S U M M A R Y

     TITLE
                         INTR BEGIN END  TERM         ORIG     PCT
                         RATE  YR.  YR.               BALC    VALUE

  FIRST MORTGAGE        0.1125  1    7    25   $   251356.  0.750
```

```
                         P R O   F O R M A
                   INVESTMENT ANALYSIS OF

                   SMALL APT. BDG.C24

                             FOR

                   RERC

              BASE CASE (CONTINUED)


  R E P O R T   S E C T I O N   N U M B E R   3          PAGE 1
  ================================================


  CASH FLOW ANALYSIS
  ==================
                                       1979      1980      1981      1982      1983      1984      1985        0         0         0
   1  GROSS INCOME                   55283.    58110.    62790.    67848.    73313.    79220.    85603.       0.        0.        0.
   2    LESS VACANCY                  1598.     1697.     1832.     1979.     2137.     2308.     2493.       0.        0.        0.
   3    LESS REAL ESTATE TAXES        5850.     6240.     6677.     7144.     7644.     8179.     8752.       0.        0.        0.
   4    LESS EXPENSES                16522.    18720.    20614.    22703.    25003.    27539.    30334.       0.        0.        0.
   5  NET INCOME                     31313.    31454.    33667.    36022.    38529.    41193.    44024.       0.        0.        0.
   6    LESS DEPRECIATION            13143.    13143.    13143.    13143.    13143.    13143.    13143.       0.        0.        0.
   7    LESS INTEREST                28181.    27953.    27697.    27411.    27091.    26733.    26333.       0.        0.        0.
   8  TAXABLE INCOME                -10011.    -9642.    -7173.    -4532.    -1705.     1317.     4549.       0.        0.        0.
   9    PLUS DEPRECIATION            13143.    13143.    13143.    13143.    13143.    13143.    13143.       0.        0.        0.
  10    LESS PRINCIPAL PAYMENTS       1930.     2158.     2414.     2700.     3020.     3378.     3778.       0.        0.        0.
  11  CASH THROW-OFF                  1202.     1343.     3556.     5911.     8418.    11082.    13913.       0.        0.        0.
  12    LESS TAXES                       0.        0.        0.        0.        0.      659.     2274.       0.        0.        0.
  13    LESS RESERVES                    0.        0.        0.        0.        0.        0.        0.       0.        0.        0.
  14  CASH FROM OPERATIONS            1202.     1343.     3556.     5911.     8418.    10424.    11639.       0.        0.        0.
  15  WORKING CAPITAL LOAN               0.        0.        0.        0.        0.        0.        0.       0.        0.        0.
  16  DISTRIBUTABLE CASH AFR TAX      1202.     1343.     3556.     5911.     8418.    10424.    11639.       0.        0.        0.
  17  TAX SAVING ON OTHER INCOME      5005.     4821.     3586.     2266.      852.        0.        0.       0.        0.        0.
  18  SPENDABLE CASH AFTER TAX        6208.     6164.     7142.     8177.     9270.    10424.    11639.       0.        0.        0.

  MARKET VALUE & REVERSION
  ========================

  CASH FLOW ANALYSIS
  ==================
                                       1979      1980      1981      1982      1983      1984      1985        0         0         0
  19  END OF YEAR MARKET VALUE      333170.   334665.   358217.   383269.   409945.   438296.   468418.       0.        0.        0.
  20    LESS RESALE COST             23322.    23427.    25075.    26829.    28696.    30681.    32789.       0.        0.        0.
  21    LESS LOAN BALANCES          249437.   247278.   244864.   242164.   239144.   235767.   231989.       0.        0.        0.
  22    PLUS CUM. CASH RESERVES          0.        0.        0.        0.        0.        0.        0.       0.        0.        0.
  23  B/4 TAX NET WORTH              60412.    63960.    88277.   114276.   142105.   171848.   203640.       0.        0.        0.
  24  CAPITAL GAIN (IF SOLD)        -12164.     2359.    37415.    73856.   111088.   151316.   192473.       0.        0.        0.
  25    CAPITAL GAINS TAX            -3041.      592.     9354.    18464.    27952.    37829.    48118.       0.        0.        0.
  26    MINIMUM PREF. TAX                0.        0.     1306.     4039.     6886.     9849.    12935.       0.        0.        0.
  27    INCOME TAX ON EXCESS DEP         0.        0.        0.        0.        0.        0.        0.       0.        0.        0.
  28    TOTAL TAX ON SALE            -1520.      592.    10660.    22503.    34838.    47678.    61054.       0.        0.        0.
  29  AFTER TAX NET WORTH            61932.    63368.    77617.    91773.   107267.   124171.   142587.       0.        0.        0.
```

RERC

```
BEFORE TAX RATIO ANALYSIS
=========================
                                                        BASE CASE (CONTINUED)
CASH FLOW ANALYSIS
==================
30   RETURN ON NET WORTH B/4 TAX        1979      1980      1981      1982      1983      1984      1985      0      0      0
31   CHANGE IN NET WORTH B/4 TAX     -0.2647    0.0810    0.4358    0.3615    0.3172    0.2873    0.2650     0.     0.     0.
32   ORIG EQUITY RTN B/4 TAXES       -23377.     3549.    24317.    25999.    27829.    29744.    31792.     0.     0.     0.
33   ORIG EQUITY PAYBACK B/4 TAX      0.0143    0.0160    0.0424    0.0705    0.1085    0.1323    0.1661     0.     0.     0.
34   PRESENT VALUE B/4 TAX            0.0143    0.0304    0.0728    0.1434    0.2438    0.3682    0.5871     0.     0.     0.
                                     306379.   304499.   318875.   332422.   345208.   357252.   368599.     0.     0.     0.

AFTER TAX RATIO ANALYSIS
========================

CASH FLOW ANALYSIS
==================
35   RETURN ON NET WORTH AFT TAX        1979      1980      1981      1982      1983      1984      1985      0      0      0
36   CHANGE IN NET WORTH AFT TAX     -0.1858    0.1227    0.3376    0.2877    0.2698    0.2548    0.2420     0.     0.     0.
37   ORIG EQUITY RTN AFT TAX         -21856.     1436.    15555.    16889.    18341.    19866.    21503.     0.     0.     0.
38   ORIG EQUITY PAYBACK AFT TAX      0.0741    0.0736    0.0852    0.0976    0.1106    0.1244    0.1389     0.     0.     0.
39   PRESENT VALUE AFTER TAXES        0.0741    0.1476    0.2329    0.3306    0.4411    0.5655    0.7844     0.     0.     0.
                                     312205.   312339.   322153.   338426.   338229.   345552.   352408.     0.     0.     0.
CASH FLOW ANALYSIS
==================
40   NET INCOME-MARKET VALUE RTO        1979      1980      1981      1982      1983      1984      1985      0      0      0
41   LENDER BONUS INTEREST RATE       0.0940    0.0940    0.0940    0.0940    0.0940    0.0940    0.0940     0.     0.     0.
42   DEFAULT RATIO                    0.        0.        0.        0.        0.        0.        0.         0.     0.     0.
                                      0.9493    0.9477    0.9142    0.8837    0.8560    0.8310    0.8083     0.     0.     0.

MODIFIED INTERNAL RATE OF RETURN ANALYSIS
=========================================
RETURN ANALYSIS WITHOUT SALE
============================

CASH FLOW ANALYSIS
==================
43   CUM. AFT TAX SPENDABLE CASH        1979      1980      1981      1982      1983      1984      1985      0      0      0
44   MOD. I.R.R. ON ORIG EQUITY        6208.    12899.    21138.    31111.    43026.    57107.    73600.     0.     0.     0.
45   MOD. I.R.R. ON CUM. EQUITY      -0.9259   -0.6076   -0.3681   -0.2194   -0.1248   -0.0619   -0.0184     0.     0.     0.
                                     -0.9259   -0.6076   -0.3681   -0.2194   -0.1248   -0.0619   -0.0184     0.     0.     0.

RETURN ANALYSIS WITH SALE
=========================

CASH FLOW ANALYSIS
==================
46   CUM. CASH LESS ORIG EQUITY         1979      1980      1981      1982      1983      1984      1985      0      0      0
47   CUM. CASH LESS CUM. EQUITY      -17169.    -7522.    14966.    39095.    66504.    97488.   132397.     0.     0.     0.
48   MOD. I.R.R. ON ORIG EQUITY      -17169.    -7522.    14966.    39095.    66504.    97488.   132397.     0.     0.     0.
49   MOD. I.R.R. ON CUM. EQUITY      -0.2049   -0.0459    0.0563    0.1085    0.1240    0.1373    0.1450     0.     0.     0.
                                     -0.2049   -0.0459    0.0563    0.1085    0.1240    0.1373    0.1450     0.     0.     0.
PROGRAM STOP AT 980
```

ENERGY RETROFIT TESTS
LARGE APARTMENT BUILDING
CLIMATE ZONE 4

FUNDAMENTAL PACKAGE

```
  CASH FLOW ANALYSIS                              1981      1983      1984      1985
  ==================                                 3         5         6         7
   5    NET INCOME                             217794.   255430.   276498.   299213.
  11    CASH THROW-OFF                          15626.    53262.    74330.    97045.
  18    SPENDABLE CASH AFTER TAX                42859.    58668.    67371.    76643.
  19    END OF YEAR MARKET VALUE              2360889.  2768863.  2997236.  3243469.
  32    ORIG EQUITY RTN B/4 TAXES               0.0296    0.1008    0.1406    0.1835
  33    ORIG EQUITY PAYBACK B/4 TAX             0.1086    0.2732    0.4006    0.5456
  37    ORIG EQUITY RTN AFT TAX                 0.0811    0.1110    0.1274    0.1450
  38    ORIG EQUITY PAYBACK AFT TAX             0.3018    0.5084    0.6358    0.7808
  44    MOD. I.R.R. ON ORIG EQUITY             -0.3154   -0.0994   -0.0426   -0.0028
  48    MOD. I.R.R. ON ORIG EQUITY              0.0910    0.1532    0.1643    0.1701

PROGRAM STOP AT 980
```

FUNDAMENTAL PACKAGE PLUS TAX CREDIT

```
  CASH FLOW ANALYSIS
  ==================                                 3         5         6         7
   5    NET INCOME                             217794.   255430.   276498.   299213.
  11    CASH THROW-OFF                          15626.    53262.    74330.    97045.
  18    SPENDABLE CASH AFTER TAX                48605.    58146.    65849.    76121.
  19    END OF YEAR MARKET VALUE              2360889.  2768863.  2997236.  3243469.
  32    ORIG EQUITY RTN B/4 TAXES               0.0296    0.1008    0.1406    0.1835
  33    ORIG EQUITY PAYBACK B/4 TAX             0.1086    0.2732    0.3996    0.5436
  37    ORIG EQUITY RTN AFT TAX                 0.0919    0.1100    0.1265    0.1440
  38    ORIG EQUITY PAYBACK AFT TAX             0.3127    0.5173    0.6437    0.7877
  44    MOD. I.R.R. ON ORIG EQUITY             -0.3077   -0.0962   -0.0404   -0.0012
  48    MOD. I.R.R. ON ORIG EQUITY              0.0921    0.1537    0.1647    0.1705

PROGRAM STOP AT 980
```

MODIFIED PACKAGE

```
  CASH FLOW ANA YSIS
  ==================                                 3         5         6         7
   5    NET INCOME                             217794.   255430.   276498.   299213.
  11    CASH THROW-OFF                          20334.    57970.    79037.   101753.
  18    SPENDABLE CASH AFTER TAX                47087.    63685.    72895.    82768.
  19    END OF YEAR MARKET VALUE              2360889.  2768863.  2997236.  3243469.
  32    ORIG EQUITY RTN B/4 TAXES               0.0385    0.1097    0.1495    0.1925
  33    ORIG EQUITY PAYBACK B/4 TAX             0.1175    0.2999    0.4378    0.5943
  37    ORIG EQUITY RTN AFT TAX                 0.0891    0.1205    0.1379    0.1566
  38    ORIG EQUITY PAYBACK AFT TAX             0.3098    0.5345    0.6724    0.8290
  44    MOD. I.R.R. ON ORIG EQUITY             -0.3097   -0.0910   -0.0342    0.0052
  48    MOD. I.R.R. ON ORIG EQUITY              0.0913    0.1535    0.1645    0.1704

PROGRAM STOP AT 980
```

```
                    P R O   F O R M A
                 INVESTMENT ANALYSIS OF

                 LARGE APT. BDGC24

                           FOR

                   RERC

               LARGE APARTMENT BUILDING
                    CLIMATE ZONE 4
                      BASE CASE

R E P O R T   S E C T I O N   N U M B E R    1          PAGE 1
==============================================

* GROSS RENT      $ 454061.  * RATE OF GROWTH OF GROSS RENT  0.0882
* EXPENSES        $ 155092.  * RATE OF GROWTH OF EXPENSES    0.1126
* R E TAXES       $  45928.  * RATE OF GROWTH OF R E TAXES   0.0669
  INCOME TAX RATE   0.5000     PROJECT VALUE GROWTH OF       2.0000
* VACANCY RATE      0.0478     WORKING CAPITAL LOAN RATE     0.
  EQUITY DISCOUNT   0.1200     EXTRAORDINARY EXPENSES      $      0.
  RESALE COST       0.0700     REINVESTMENT RATE             0.0850
  WKG CAPITAL RS $       0.    CAPITAL RESER INTEREST RATE   0.
  INITIAL COST $  2114522.     INITIAL EQUITY REQUIRED   $  528631.

  ALL '*' VALUES ARE AVERAGE AMOUNTS FOR HOLDING PERIOD. OF  7 YRS.
```

```
                    P R O   F O R M A
                 INVESTMENT ANALYSIS OF

                 LARGE APT. BDGC24

                           FOR

                   RERC


R E P O R T   S E C T I O N   N U M B E R    2          PAGE 1
==============================================


            C O M P O N E N T   S U M M A R Y

   TITLE               PCT. BEGIN USEFUL  DEPR
                       DEPR  USE   LIFE  METHOD       COST    SCH
SHELL                  0.90   1     30.    2     $  962953.   7
PLUMBING               1.00   1     25.    2     $   22837.   0
HVAC                   1.00   1     15.    2     $  142730.   0
ELECTRIC               1.00   1     20.    2     $   98960.   0
INTERIOR FINISH        0.90   1     15.    2     $  498604.   0
OTHER                  1.00   1     13.    2     $  176986.   0
LAND                   0.     1      0.    0     $  211452.   0

             M O R T G A G E   S U M M A R Y

    TITLE                INTR BEGIN END  TERM        ORIG     PCT
                         RATE  YR.  YR.              BALC    VALUE

FIRST MORTGAGE          0.1125  1    7    25    $ 1585892.  0.750
```

```
                    P R O   F O R M A
                 INVESTMENT ANALYSIS OF

                 LARGE APT. BDGC74

                          FOR

                      RERC

               BASE CASE (CONTINUED)


R E P O R T   S E C T I O N   N U M B E R   3          PAGE 1
==================================================


CASH FLOW ANALYSIS                      1979
==================
                                           1        2        3        4        5        6        7        0        0        0
 1   GROSS INCOME                    348280.  376602.  410328.  447075.  487116.  530744.  578282.       0.       0.       0.
 2     LESS VACANCY                   16649.   17988.   19607.   21372.   23295.   25392.   27677.       0.       0.       0.
 3     LESS REAL ESTATE TAXES         37507.   39803.   42510.   45400.   48487.   51785.   55306.       0.       0.       0.
 4     LESS EXPENSES                 109307.  123697.  137392.  152254.  168731.  187002.  207259.       0.       0.       0.
 5   NET INCOME                      184817.  195114.  210819.  228049.  246602.  266566.  288040.       0.       0.       0.
 6     LESS DEPRECIATION              87796.   87796.   87796.   87796.   87796.   87796.   87796.       0.       0.       0.
 7     LESS INTEREST                 177798.  176355.  174742.  172937.  170919.  168661.  166136.       0.       0.       0.
 8   TAXABLE INCOME                  -80777.  -69037.  -51719.  -32684.  -12113.   10108.   34108.       0.       0.       0.
 9     PLUS DEPRECIATION              87796.   87796.   87796.   87796.   87796.   87796.   87796.       0.       0.       0.
10     LESS PRINCIPAL PAYMENTS        12174.   13617.   15230.   17035.   19053.   21311.   23836.       0.       0.       0.
11   CASH THROW-OFF                   -5155.    5142.   20847.   38078.   56630.   76594.   98068.       0.       0.       0.
12     LESS TAXES                         0.       0.       0.       0.       0.    5054.   17054.       0.       0.       0.
13     LESS RESERVES                      0.       0.       0.       0.       0.       0.       0.       0.       0.       0.
14   CASH FROM OPERATIONS             -5155.    5142.   20847.   38078.   56630.   71540.   81014.       0.       0.       0.
15   WORKING CAPITAL LOAN              5155.      13.       0.       0.       0.       0.       0.       0.       0.       0.
16   DISTRIBUTABLE CASH AFR TAX           0.       0.   20834.   38078.   56630.   71540.   81014.       0.       0.       0.
17   TAX SAVING ON OTHER INCOME       40388.   34519.   25859.   16342.    6056.       0.       0.       0.       0.       0.
18   SPENDABLE CASH AFTER TAX         40388.   34519.   46694.   54419.   62687.   71540.   81014.       0.       0.       0.

MARKET VALUE & REVERSION
========================

CASH FLOW ANALYSIS
==================
                                         1        2        3        4        5        6        7        0        0        0
19   END OF YEAR MARKET VALUE     2003416. 2115036. 2285280. 2472056. 2673168. 2889573. 3122354.       0.       0.       0.
20     LESS RESALE COST            140239.  148053.  159970.  173044.  187122.  202270.  218565.       0.       0.       0.
21     LESS LOAN BALANCES         1578872. 1560114. 1544870. 1527836. 1508783. 1487472. 1463637.       0.       0.       0.
22     PLUS CUM. CASH RESERVES           0.       0.       0.       0.       0.       0.       0.       0.       0.       0.
23   B/4 TAX NET WORTH             284305.  406870.  580440.  771177.  977263. 1199831. 1440152.       0.       0.       0.
24   CAPITAL GAIN (IF SOLD)       -163549.   28053.  274176.  535674.  810504. 1099556. 1403839.       0.       0.       0.
25     CAPITAL GAINS TAX           -40887.    7013.   68544.  133919.  202626.  274889.  350960.       0.       0.       0.
26     MINIMUM PREF. TAX                0.     604.   19063.   38676.   59288.   80967.  103788.       0.       0.       0.
27     INCOME TAX ON EXCESS DEP         0.       0.       0.       0.       0.       0.       0.       0.       0.       0.
28     TOTAL TAX ON SALE           -20444.    7617.   87607.  172594.  261914.  355856.  454748.       0.       0.       0.
29   AFTER TAX NET WORTH           304749.  399252.  492832.  598583.  715350.  843975.  985405.       0.       0.       0.
```

```
BEFORE TAX RATIO ANALYSIS
=========================
                                                         BASE CASE (CONTINUED)
CASH FLOW ANALYSIS                 1979
==================
                                      1        2        3        4        5        6        7
30   RETURN ON NET WORTH B/4 TAX   -0.4522   0.4492   0.4778   0.3942   0.3407   0.3061   0.2820            0          0          0
31   CHANGE IN NET WORTH B/4 TAX  -244326.  122565.  173570.  190737.  206087.  222567.  240322.    0.          0.          0.
32   ORIG EQUITY RTN B/4 TAXES     -0.0098   0.0097   0.0394   0.0720   0.1071   0.1449   0.1855          0.          0.          0.
33   ORIG EQUITY PAYBACK B/4 TAX    0.       0.       0.0394   0.1114   0.2186   0.3539   0.5072    0.          0.          0.
34   PRESENT VALUE B/4 TAX         1835132. 1909742. 2013372. 2114527. 2211085. 2303235. 2391177.   0.          0.          0.
                                                                                                        0.          0.          0.

AFTER TAX RATIO ANALYSIS
========================

CASH FLOW ANALYSIS
==================
                                      1        2        3        4        5        6        7
35   RETURN ON NET WORTH AFT TAX   -0.3471   0.4234   0.3513   0.3250   0.2998   0.2798   0.2636            0          0          0
36   CHANGE IN NET WORTH AFT TAX  -223882.   95108.  112039.  125363.  137379.  150304.  164251.    0.          0.          0.
37   ORIG EQUITY RTN AFT TAX        0.0764   0.0653   0.0883   0.1029   0.1186   0.1353   0.1533          0.          0.          0.
38   ORIG EQUITY PAYBACK AFT TAX    0.0764   0.1417   0.2300   0.3330   0.4516   0.5869   0.7401    0.          0.          0.
39   PRESENT VALUE AFTER TAXES     1894049. 1967752. 2033494. 2097701. 2158769. 2216689. 2271499.   0.          0.          0.
                                                                                                        0.          0.          0.
CASH FLOW ANALYSIS
==================
                                      1        2        3        4        5        6        7
40   NET INCOME-MARKET VALUE RTO    0.0923   0.0923   0.0923   0.0923   0.0923   0.0923   0.0923            0          0          0
41   LENDER BONUS INTEREST RATE     0.       0.       0.       0.       0.       0.       0.        0.          0.          0.
42   DEFAULT RATIO                  0.9670   0.9523   0.9014   0.8670   0.8359   0.8078   0.7826    0.          0.          0.
                                                                                                  0.          0.          0.

MODIFIED INTERNAL RATE OF RETURN ANALYSIS
=========================================
RETURN ANALYSIS WITHOUT SALE
============================

CASH FLOW ANALYSIS
==================
                                      1        2        3        4        5        6        7
43   CUM. AFT TAX SPENDABLE CASH    40380.   78340.  131692.  197306.  276763.  371828.  484447.            0          0          0
44   MOD. I.R.R. ON ORIG EQUITY    -0.9236  -0.6150  -0.3708  -0.2184  -0.1214  -0.0570  -0.0124          0.          0.          0.
45   MOD. I.R.R. ON CUM. EQUITY    -0.9236  -0.6150  -0.3708  -0.2184  -0.1214  -0.0570  -0.0124    0.          0.          0.
                                                                                                  0.          0.          0.

RETURN ANALYSIS WITH SALE
=========================

CASH FLOW ANALYSIS
==================
                                      1        2        3        4        5        6        7
46   CUM. CASH LESS ORIG EQUITY   -203937.  -51038.   95894.  267258.  463482.  687172.  941222.            0          0          0
47   CUM. CASH LESS CUM. EQUITY   -203937.  -51038.   95894.  267258.  463482.  687172.  941222.           0.          0.          0.
48   MOD. I.R.R. ON ORIG EQUITY    -0.3858  -0.0495   0.0571   0.1077   0.1342   0.1489   0.1573          0.          0.          0.
49   MOD. I.R.R. ON CUM. EQUITY    -0.3858  -0.0495   0.0571   0.1077   0.1342   0.1489   0.1573    0.          0.          0.
                                                                                                  0.          0.          0.
PROGRAM STOP AT 980
```

WORKING PAPER

#4

Methods and Detailed Calculations Used in Estimating the Retrofit Potential of Different Building Types

Energyworks, Inc.
West Newton, Mass.

With introduction
and explanations by
OTA Staff

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Section O.............................. Load Profiles for Thirteen Building Types in the St. Louis Climate Zone for Three Levels of Investment in Retrofit Packages

Section P.............................. Algorithms Used in Calculating the Cumulative Savings of Retrofits Combined in Packages

Section Q.............................. Computer Program Used in Calculating Savings from Retrofit Packages

Section R.............................. Impact of Retrofit Packages on Key Parameters

Section A: Introduction (by OTA)

The material that is presented in the sections which follow was submitted by Energyworks, Inc. in support of the calculations of the retrofit potential of different building types. The findings for this analysis were presented in Chapter 3 of the full report Energy Efficiency of Buildings in Cities. The material describes two separate sets of calculations:

(1) Calculations of the applicability and cost effectiveness of individual retrofits to different building types. Savings and costs are calculated as if each retrofit were the only one and cannot be cumulated. (Sections B-L)

(2) Calculations of the cumulative costs and savings of selected retrofits installed in packages of low, moderate and high cost compared to savings. These calculations take into account interactive effects among individual retrofits. Sections M-O.

This material is organized as follows:

Section B: Project methodology (for the calculations of costs and savings from individual retrofits only).

Section C: Description of the building models used in the calculations

Section D: Detailed parameters of the building models.

Section E: Cost/savings ratios using fuel-adjusted savings for retrofits to 43 building types in the St. Louis climate zone.

Section F: Cost/savings ratios using fuel-adjusted savings for four building types in four climate zones.

Section G: Cost/savings ratios for solar retrofits to three building types in four climate zones.

Section H: Costs of each retrofit for each building type.

Section I: Energy savings from each retrofit for each building type -- without fuel adjustment factor.

Section J: Cost/savings ratios without fuel adjustment for 43 building types in four climate zones.

Section K: Fuel factors used in adjusting energy savings in Btus for the difference between fuel oil at $1.00/gal. and electricity at 6¢/kwh.

Section L: Individual data sources and algorithms used in calculating costs and savings for individual measures, including the list of references from Appendix D of the report.

Section M: Introduction to methodology for calculations of cumulative costs and savings from retrofit packages.

Section N: Data on base energy use, cumulative energy savings and cost per million Btu for retrofit packages of low, moderate and high cost compared to savings as shown graphically in Appendix B of the full report.

Section O: Load profiles for thirteen building types in the St. Louis climate zone for three levels of investment in retrofit packages.

Section P: Formulas for calculating interactive energy savings for selected retrofits.

Section Q: Computer program for calculating interactive energy savings.

Section R: Impact of retrofits on key building model parameters.

The cumulative savings calculations were done after the individual retrofit savings calculations in response to comments by reviewers.

The material in these working papers complements material in Appendix tables of the report itself, namely:

- Tables 3A-3D at the end of Chapter 3 of the report present information in condensed form on the basic assumptions used in developing the building models.
- Appendix A shows detailed retrofit lists for 13 building types for the St. Louis climate.
- Appendix B shows graphs of cost per million Btu and savings from cumulative retrofit packages for each of the 13 building types.
- Appendix C gives a description of each of the retrofits.

The material presented in these working papers does not in all cases exactly correspond to what is presented in the chapter because in some cases Energyworks revised the calculations in response to the comments of reviewers, or OTA staff. Wall insulation for frame houses and the conversion of complex reheat to variable air volume systems are examples of retrofitting for which calculations were changed substantially before publication.

For further information on any of this material, interested readers should contact Gordon Kramer of Energyworks and/or Mary Procter of the Office of Technology Assessment.

Section B: Project Methodology for the Calculations of Costs and Savings

This is the description of the methodology for calculating individual retrofits as presented in the final report from Energyworks of West Newton, Mass. in February 1981.

THE POTENTIAL FOR RETROFIT IN BUILDINGS IN U.S. CITIES

FINAL REPORT

Prepared for:

Office of Technology Assessment
U.S. Congress
600 Pennsylvania Avenue, S.E.
Washington, D.C. 20510

Prepared by:

Energyworks, Inc.
45 Border Street
West Newton, MA 02165

Allan Ackerman
Gordon Kramer
Eric Tarini
Tom Timko

Energyworks
Inc.

1.1 FORWARD

This report characterizes the task ahead of "retrofitting," or renovating to make more energy efficient, buildings in urban areas of this country. Like the rest of our building stock, existing urban structures can use far less energy than they do today. As the costs of new construction continue to rise, our incentives to retrofit rather than replace our increasingly dilapidated city buildings become stronger. In addition, as a strategy for energy upgrade retrofit and rehabilitation preserves the historic character of our cities, and, when applied to residential areas is less disruptive to the social fabric of neighborhoods.

From an energy point of view, city buildings have some hereditary advantages. The higher density of cities almost always means greater energy efficiency. Urban buildings have less surface area per unit of volume enclosed; for example, rowhouses typically have two exposed walls, not four, and multistory downtown department stores enclose more space for the same amount of exposed "skin" than do suburban shopping malls. Urban buildings protect one another from the frigid effects of winter winds and, as a result, leak less air than thin, more exposed rural counterparts. Naturally, the energy picture for city structures is not completely positive - some solar retrofit options are less applicable because of reduced available collector area in relation to building floor area, and because buildings in cities shade one another, already pre-empting each other's "solar rights." In addition, not all U.S. cities are particularly dense, and contain as much energy wasteful housing and sprawling single-story commercial development as any suburban or rural area.

1.2 STUDY QUESTIONS AND METHOD

What do we face in retrofitting our urban building stock? How do different building types differ in their potential for retrofit? What kind of retrofit will it take - a lot of insulation, a lot of new boilers, a lot of solar collectors? Does the answer lie in behavioral changes - changing the way we use the buildings and not the buildings themselves? Are some urban buildings energy "dinosaurs" that we should demolish rather than continue to pay an endless, unreduceable fuel bill? What kind of retrofit costs are we talking about per square foot and at what likely rates of return and payback periods? Will we have to invest at marginal rates of return to capture the majority of the savings possible? Can we dispense with elaborate energy "audits" for every single building, and instead proceed immediately to some retrofit measures once a few key facts about a building are known?

To those who have already dealt with the problem of designing a retrofit program for a single building, a group of municipal buildings for a city, or for an entire class of buildings in a region, these are familial questions. More comprehensively than before, this study attempts to provide a framework for the answers to these questions, and attempts to provide an initial set of the answers themselves.

Working with a group of five hypothetical building usage types or building models, selected to be representative of urban buildings, the project team estimated costs and fuel savings incurred by the retrofit of these buildings. The computations were performed for four climatic areas, and for three hypothetical levels of investment. In addition, the five building models were each varied considerably to reflect the variety of building structures and mechanical systems that exist in the U.S. urban building stock. The project team has experience both in energy auditing and in retrofit. Throughout, study assumptions were reviewed by a group of building professionals whose experience is similar to that of the study team, but who represent several geographically diverse U.S. cities.

The results of this effort has been to collect, organize, and display the retrofit potential of nearly every building type found in U.S. cities. In brief, the study team has achieved this by performing two general tasks:

1. Establish a classification scheme for buildings that is meaningful to study users, meaningful in terms of the way in which retrofit measures apply to buildings, and which is a minimum number of types. Further, select a list of retrofit measures for consideration which is comprehensive, but limited to measures for which adequate cost and savings information exists.

2. Determine the set of retrofit measures which physically applies to each building type, and perform computations which quantitatively establish groups of retrofit measures applying to each building type given three different levels of investment criteria.

In more detail, for each building type examined in a particular climatic area for a particular level of investment, this report displays those retrofit measures which could be physically as well as financially applicable, the estimated retrofit construction costs and fuel savings if each measure was implemented individually, and the estimated construction costs if applicable measures were implemented together. To a lesser extent, fuel savings estimated to accrue from the implementation of these groups or "packages" of measures were also computed.

1.3 LIMITATIONS OF STUDY

The four U.S. cities chosen are not climatically average, and were selected to complement other concurrent research activities by the OTA. Results can be extended to other U.S. cities, but with care to properly account for climatic variation.

The estimated fuel savings figures are based on a great many assumptions about "average" conditions in U.S. urban buildings, and should be taken in that light. In addition, in estimating savings that may accrue from the installation of "packages" of measures, the study team has not been able to completely and rigorously account for the complicated interactive effects between retrofit measures. For example, replacing an old boiler with a more efficient one will result in greater fuel savings if done before the building's walls have been insulated rather than afterwards. These effects almost always cause total savings accruing from a retrofit package to be less than the sum of its parts. Major estimated effects of this type have been accounted for, however.

This is a qualitative study. The work has been done without reference to the total quantities of various types of buildings in U.S. cities, and draws no conclusions except on a unit basis. Properly and carefully combined with aggregate data, projections of retrofit potential for groups of five or 50,000 buildings can be made, although with a lot more confidence on the cost side than for savings.

Although the various hypothetical building models used for the study are probably very representative of urban buildings, the actual existing physical state of existing buildings in cities is not known. Although we known that urban buildings contain plenty of opportunity for retrofit, the study could only estimate the amount of retrofit that has already occurred. This certainly means that the retrofit potential of a building or group of buildings is less than that represented in this study by the total of the three levels of retrofit investment. But these three levels have been chosen as three, seven, and sixteen year simple payback periods, and it may be assumed that the owner of any given building will roughly proceed in order of cost-effectiveness. (There are probably many notable exceptions to this, probably the result of building owners' responding to sales efforts for individual, often high cost and long payback retrofit measures rather than proceeding more methodically.) Therefore, retrofit potential estimates for groups of buildings likely to have been partially retrofitted should be taken from the seven and sixteen year payback investment level computations, in that order.

The study is concerned with one class of the full arsenal of effective techniques available to improve the energy efficiency of any building: retrofit. The other two major areas of potential are left out: changes in the way buildings are used (e.g. thermostat settings, better operating and maintenance practices, open windows instead of air conditioning), and improvements in energy efficiency that can only be done as part of a rehab program (e.g. replacment of the heating distribution system or installation of a completely new wall system).

Lastly, computations in this study of retrofit potential have no reference to the actual energy efficiency of urban buildings. Therefore, a computed result of relatively low retrofit potential for a given building type (and this study identifies quite a few in that category) does not necessarily label that building type an energy "dinosaur." Low retrofit potential is a very strong indication of energy obsolescence, though, since a lack of retrofit potential is indicated by this study to be strongly associated with buildings whose various components are relatively inefficient - decentralized heating and cooling systems and clad wall construction, to name two.

1.4 HOW TO USE THIS REPORT

This report provides information of the energy conservation retrofit potential of buildings, cross-indexed by usage type, architectural features, mechanical system, and climate. It therefore covers a broad range of the actual building stock, furnishing useful guidelines to professionals in a number of different fields who are interested in energy conservation.

To the policy maker, the report provides information on several different levels, depending on the need. Legislative or executive policy makers seeking to design programs to encourage energy conservation, such as tax credits, low-interest guaranteed loans, or grants, would be interested in determining which building types are likely to yield the greatest benefits in terms of conserved energy, given a limited amount to available funding. They may be interested in locating the features most indicative of retrofit potential within a single usage type, such as small residential, or in scanning the entire range of usage types, residential and commercial, as an aid in forming broad-based policy decisions. A "first-cut" approach would be to scan the summary data in Figure 1 and Table 1 (section 2.1.1 an 2.1.2, respectively) and to read the analysis of results in sections 2.2.1 and 2.2.5. This would indicate general trends in retrofit potential. For national policy makers, the entire range of figures and tables, across all climates zones, would be of interest; the local policy maker would be more interested in a single climate zone. In general, the data on a single page of figures or tables represents one climate zone only, with the other zones following on separate sheets. Those interested in analyzing more detailed results could use the quanitative data, summarized in Table 2 (section 3.1) and presented in full detail in Table 3 (section 3.2).

This report is also of use to the policy maker needing to determine the overall potential for jobs and/or investment that could be generated by energy conservation projects within a given city or region. The detailed data in section 3 can be summarized within a particular climate zone. This data can be combined with data on the population and condition of the local building stock to yield estimates on the overall retrofit investment potential within a given area.

A member of a real estate trade association may be interested in one particular usage type, such as single family, small multifamily, etc., across all architectural styles, mechanical system types, and climates. One set of figures within Figure 1 (section 2.1.1) is organized with data grouped together according to usage type, one sheet for each climate zone. this would be particularly useful for observing general trends in retrofit potential of that building type. Tables 1, 2, and 3 are also organized with all data for a particular building type grouped together, so that information can be easily located at any desired level of detail. Those interested in a particlur usage type may also want to read the material on the definition and classification of building types in section 4, to determine how closely the building models conform to the actual buidling population of interest.

The individual building owner or operator will be interested in a particular building in a particular climate zone. Detailed information is provided in Table 3: each page of the table provides a list of measures that fall within low, medium, and high investment levels for a given usage type, architectural type, mechanical system type, and climate. These parameters are listed at the head of each table. The cost-effectiveness of each measure , in dollars per million BTU of adjusted fuel savings potential per square foor, at each investment level, is given at bottom of th page. It would also be useful to read the building model data in sections 4.1 and 4.2, the conservation measures descriptions in section 5.2, and the assumed measure costs in Table 7 (section 5.4), to determine how closely the building model and the listed measures fit the actual building.

The energy conservation professional, such as a consulting engineer, designer, or contractor working with energy conservation projects, may be interested in the effectiveness of a number of differnt conservation measures across all building tyes in a particular region. Section 5 provides detailed information on the selection, description, and calculation algorithms for the various conservation measures. Table 1 illustrates the impact of each measure on the different building types, in terms of whether the measure falls into a low, medium, or high payback category. Actual cost/savings ratios are provided for each applicable measure in each building type and climate in Table 3. The energy professional may also be interested in the building model data in section 4 and the calculation methodology outlined in section 2.0.

The manufacturer, installer, or contractor of a particular conservation device or process may be interested in the impact of the measure across all building types, in a single region of perhaps across all climate zones. The measure can first be located in Table 1 to determine the general impact across all building types, in terms of low, medium, or high payback level. The quantified effect on a particular building type can be located in Table 3, It would also be useful to read the conservation measure materials in section 5 for that particular measure, to determine how closely the modeled measure conforms to the actual device or process.

1.5 BUILDING TYPE DESCRIPTIONS

Building types were chosen to represent as much of the existing older urban building stock as possible within a reasonably small number of types. Obviously many buildings are not closely represented by any of these types, but the types described here may be used as a rough guideline. A detailed discussion of the choice of building elements is given in section 4.1.

Buildings are classified in 5 major usage types: single family (attached and rowhouse), small multifamily, small commercial, large commercial, and large multifamily. Within each usage type are some or all of the following structural types: cavity wall, masonry bearing wall, and clad wall. The architectural features of each type are a function of both usage type and structural type. There are also four mechanical system types, as described in section 4.1, which are partly determined by usage type, but are independent of structural type: air, water, decentralized, and complex.

SINGLE FAMILY, DETACHED

This is a wood cavity wall building of 2 stories, with wooden-sash double-hung windows without storm windows. There is a wooden pitched roof over an unheated attic, with the roof line running along the long axis of the house. Total conditioned space is 2,000 square feet. There is a full basement and two solid wood doors, one at each end of the house. This type may have a central air system (providing both heating and cooling), a hot water heating system with window air conditioners, or a decentralized heating system (electric baseboard) with window air conditioners.

SINGLE FAMILY, ROWHOUSE

A 2-story building, attached on both of its long-axis sides, with solid uninsulated masonry walls. Total conditioned space is 2,000 square feet. The roof is a wood deck, flat or slightly pitched from front to rear, over an uninsulated crawl space. Windows, doors, and basement are similar to the detached house. Heating and cooling systems are also similar. Both single-family types have domestic hot water generated by a separate water heater, fuel-fired for the air and water systems, electric for the decentralized system.

SMALL MULTIFAMILY

A rectangular-shaped, 3-story detached building with 15,000 square feet of conditioned space. There are 15 apartments, 5 on each floor. The cavity-wall and masonry-wall types have wooden-sash and double-hung windows, similar to the single-family types; the clad-wall type has metal-sash double-hung windows. The roof is flat, wood for the cavity wall and structural concrete for the masonry and clad walls. There are two aluminum-frame glass double doors, one on each long side of the building. A full basement contains the heating system (for air and water systems), and a central domestic water heater serving all apartments.

SMALL COMMERCIAL

This has the same shape, size, and enclosed space as the small multifamily. It contains mainly office space, with some retail space on the ground floor. The walls, roof, doors, and basement are similar to the small multifamily. The cavity wall type has wooden-sash double-hung windows, the masonry wall metal-sash double-hung windows, and the clad wall metal-frame casement windows. This type may have a complex mechanical system as well as air, water, or decentralized. Domestic hot water is supplied by a central heater or by a tankless coil in the boiler for water heating systems, and is available only during the heating season.

LARGE COMMERCIAL

This is an 8-story rectangular detached building with 100,000 square feet of conditioned space, occupied primarily by offices. Only the masonry wall and clad wall types are included in this usage category. Both structural types have a concrete deck flat roof, metal-sash casement windows, and 4 aluminum-framed glass double doors, one on each side of the building. A full basement contains the mechanical systems (for all types except decentralized) and the domestic hot water system. The systems are as described above for the small commercial type.

LARGE MULTIFAMILY

This is an 8-story detached building in a courtyard shape, containing 100,000 square feet of conditioned space. Walls may be masonry or clad wall; both types have metal-sash residential casement windows. The roof is a flat concrete deck. There are three aluminum-frame glass double doors, one on the side of the courtyard facing the street, one opposite in the rear of the building, and one on the side. The mechanical system may be either air, water, or decentralized. There is a central domestic hot water system serving the entire building, located in the basement, which may be either a separate heater or a tankless coil for water systems.

2.0 SUMMARY OF PROJECT METHODOLOGY

The development of cost/savings data for the various conservation measures, building types, and climate zones, involves 4 major phases of data gathering and calculation:

I. Develop building models and climatic data

II. Calculate base case building energy use profile

III. Develop cost/savings matrices using data generated in Phases I and II in conjunction with cost data.

IV. Recalculate low, medium, and high-payback investment packages from Phase III data.

PHASE I

A. Develop Building Models

A set of parameters is developed to describe the major characteristics of the building and its usage pattern in the following categories.

1. Architectural/structural
2. Mechanical
   a. Heating
   b. Cooling
   c. Domestic hot water
   d. Lighting
3. Occupancy, use of mechanical systems

The selection and classification of building model parameters is discussed in Section 4.1, and numerical values for each parameter are tabulated in section 4.2.1.

B. Develop Climatic Data

The climatic parameters required to calculate the building energy use profile in each zone are identified and gathered from established sources. Items 20 and 21 in the bibliography were the main sources for climatic data. The parameters are presented in tabular form in section 4.2.1.

PHASE II

Calculate Building Energy Use Profiles

The Phase I data is used to develop numerical profiles of the energy use of the base building models in various categories. A list of the energy use parameters, along with the equations used to calculate each one, is presented in section 4.2.2. The data generated in Phase II, representing "base case" annual energy budgets for each building type and climate zone, are presented in Table 4, section 4.3.

PHASE III

A. Identify Conservation Measures

A set of measures is developed with general applicablity to older urban residential and commercial buildings. All but a few are applicable to all of the major physical/usage (PU) types, and all climate zones (although cost-effectiveness may vary considerably with climate.)

B. Develop Energy Savings Algorithms

An algorithm for calculating the energy savings is developed for each measure, using parameters developed in Phases I and II. Some of the algorithms are fairly well-established, and are available directly from sources in the bibliography. For the most part, however, new algorithms were written based on information obtained from manufacturers of conservation products, sources listed in the bibliography, and the experience of consultants and designers working in the energy conservation field.

Prose descriptions of the measures are given in section 5.2.3. A set of "Conservation Measure" sheets is also presented with the support material in section 5.3. Each sheet provides the following information:

1. A brief description of the measure.

2. A list of Phase I and Phase II data inputs required for the energy savings calculation.

3. A list of PU and mechanical system types to which the measure is applicable.

4. Assumptions made about the base building model and/or the measure in developing the algorithm.

5. Factors limiting the accuracy of the algorithm.

6. The equation used to calculate savings. Equations are presented in the form in which they were written for programmed calculation.

7. Major sources used in developing the algorithm, keyed by number to the bibliography.

Wherever possible, the interactive effect of a conservation measure between different building systems is incorporated into the algorithm. For example, measures involving reduced energy for lighting include the effect of reduced cooling load and increased heating load as well as the reduction of lighting energy use.

Interactive effect is not considered in cases such as building envelope load reduction, where the reduction affects some decrease in the seasonal operating efficiencies at heating and cooling equipment, due to reduced operating hours. These effects are dealt with to some degree in Phase IV.

C. Compile Cost Data

For each measure and building type, a project cost estimate is developed, using estimating manuals, product literature and catalogs, and information obtained from contractors and consultants. Costs are listed in section 5.4, Table 7.

D. Calculate Cost/Savings Ratios

For each building type and climate zone, the energy savings resulting from each applicable conservation measure is calculated, using the equations given in section 5.3 and the building and climate parameters in section 4.2.1 and 4.2.2. Savings are calculated in terms of MMBTU (millions of BTUs) per year. Cost/savings ratios are then developed by dividing the cost, specific to the measure, building type, and climate, by the calculated savings.

PHASE IV

Recalculate Investment Packages from Phase III Data

The objectives are (1) To develop lists of measure that, for a given building type and climate, fall within a low, medium, or high investment category, representing maximum payback periods of 2, 7, or 16 years, respectively. (2) To calculate the net cost per square foot and energy savings per square foot that would result from simultaneously implementing all measures in a given investment list. The savings and cost/savings ratios calculated in Phase III cannot be directly sorted into lists and added up for several reasons:

1. They represent savings of different types of fuel (oil or electricity) which have different costs per BTU; therefore the payback period is dependent on the type of fuel saved.

2. A number of measures are mutually exclusive within a given building type, in that it would either be physically impossible or would not make sense to implement both in the same building. Therefore adding such measures in the same lists would not provide a realistic appraisal of retrofit potential.

3. Simultaneous implemenation of several measures produces interactive effects whereby the total energy savings for the package is different, usually less, than the sum of each measure implemented by itself. Therefore, most measure packages show unrealistically high energy savings unless interactive effects are accounted for.

The recalculation process was programmed for microcomputer operation. The basic calculation steps are outlined below.

A. Fuel Cost Factor Assignment

It is necessary at some point to sort measures into 2, 7, and 16 year payback categories. Where the fuel saved is oil at $1.00/gallon ($7.143/MMBTU), these levels are represented by cost/savings ratios of $14/MMBTU, $50/MMBTU, and $114/MMBTU, respectively. Where the fuel is electricity at $.06/KWH ($17.58/MMBTU), the payback levels are proportionally lower due to the higher value of the fuel saved. Measures are sorted according to the type of fuel saved (for decentralized systems, all measures involve electrical energy savings). Where the fuel is electricity, the cost/savings ratio is multiplied by $7.143/$17.58, or 0.4063, so that the same investment level cutoffs can be applied across the board to all measures and yield the true payback. Measures with mixed fuel savings are multiplied by a factor adjusted for the proportion of each fuel, and oil-saving measures are left unchanged.

B. Delete Mutually Exclusive Measures

Where two measures are physically applicable to a given building type, but could not or would not ordinarily be implemented together (such as measures "HVAC-1: Replace Burner" and "HVAC-2: Replace Boiler"), all but one measure in a mutually exclusive set must be deleted so that realistic measure packages can be developed. Within each building type and climate, the overall measure list is scanned to locate such sets. Mutually exclusive measures are then ordered according to fuel-adjusted cost/savings ratio, and the measure with the lowest ratio (i.e., the most cost-effective) within each set is retained and the other(s) deleted. Mutually exclusive measures are noted in Table 6, section 5.2.

C. Account for Interactive Effects **

The interaction between various measures is generally complicated. Some issues pertaining to interaction are discussed in section 5.2.2, and interactive effects between all measures are qualitatively displayed in Table 6, section 5.2.2. It was not possible to deal with all interactions between measures in a given building type: the calculation task would have been enormous, even with computer assistance. Two principal types of interaction occur: interaction between measures within the same energy use category (Building Envelope, HVAC Systems, Domestic Hot Water, Lighting), and interaction between categories. Interaction within categories is dealt with in the following ways:

Building Envelope: The savings for measures which effect the same building element, such as storm windows and reflective window films or thermal window shades, cannot be directly added as the aggregate net reduction in heat loss or gain is not the sum of reductions calculated for each measure. The aggregate savings for each possible combination of measures affecting the same element is first determined. Then the measure lists are scanned for such combinations, and savings are reduced (cost/savings ratios increased) to reflect the ratio of real aggregate savings to the sum of non-interactively calculated savings.

Heating and Cooling (HVAC) Systems: Where non-exclusive measures improving the seasonal efficiency of a heating system are implemented together (such as installing a new burner, an automatic vent damper, and a stack heat reclaim system on the same boiler), the percentage reduction in seasonal fuel consumption is considerably less than the sum of savings calculated separately for each measure. The net fuel savings for each feasible combination of efficiency-related heating measures is estimated or calculated; all measures within an interactive set are then adjusted to reflect the real fuel savings in combination.

While there are many other types of interaction within the HVAC category, it was not possible to deal with them quantitatively within the scope of this project.

Domestic Hot Water: Some measures in this category involve reducing the base load energy use, such as installing flow restrictors, while others involve improving the fuel-efficiency by which the load is met, such as installing vent dampers or using an air-to-water heat pump. Since the savings for efficiency-improving measures is proportional to the base load, all such measures are adjusted to account for a reduced base load, where a flow-reducing measure was to be simultaneously implemented. The flow-reducing savings are also reduced to account for the improved fuel-efficiency whereby the load is met.

Lighting: Where measure "L-3: Task Lighting", which involves the reduction of the general lighting level, is implemented in combination with general lighting efficiency measures, such as replacing incandescent lighting with fluorescents or hybrid lamps, the real savings in combination is less than the sum of separate savings, since the efficiency improvement is applied to a reduced total amount of lighting, and the hybrid lamps replace a more efficient form of lighting than in the base case. Appropriate reduction ratios are calculated and applied to each measure in such combinations.

It was not possible to deal quantitatively with interaction between energy use categories: the nature of such interactions requires that the base building energy profiles be recalculated, which changes the cost-effectiveness of almost all measures simultaneously. The best way to deal with this would be to recalculate building energy profiles based on a modified building where all proposed measures were installed, and then determine the differences in energy cost between the base case and the modified case. This was beyond the scope of this project. Therefore, many measure packages may have a net savings which is somewhat less than calculated.

D. Assign Investment Levels **

After all measure lists have been adjusted for real fuel cost, mutually exclusive measures deleted and adjusted for interaction, measures are sorted into low, medium, and high investment levels, according to the criteria described in part A. An additional category is created for feasible measures with payback periods longer than 16 years. These investment packages are listed for each building type and climate zone in Table 3.

E. Recalculate Package Costs and Savings **

The net cost/s.f. for each package is calculated by scanning each package list and adding the cost of each measure (specific to the building type and climate zone), divided by the gross square footage of the building. Net savings totals are calculated by dividing each cost figure by the appropriate adjusted cost/savings ratio, to reflect the real savings by a uniform cost criterion. Adjusted savings are than added directly for 11 measures in a given package. This data is summarized in Table 2.

** These steps were performed by Energyworks, but are not included in this Working Paper because they were superseded by the analysis of retrofit packages which is described in Sections M through R.

Section C: Description of the Building Models Used in the Calculations

It should be pointed out that these building models are assumed to lack any energy efficient features such as attic insulation, wall insulation or storm windows. Thus they represent the most energy-inefficient elements of the central city building stock and not the typical elements. Retrofits to buildings with some insulation, or storm windows, would produce less savings than are reported in Section I.

The detailed assumptions about efficiency of heating systems, U-values, climate data, etc. are shown in the next section, Section D.

4.1 DEVELOPMENT AND CLASSIFICATION OF BUILDING MODELS

4.1.1 Introduction

Matrix descriptors have been chosen to maximize the number of real buildings covered by the matrix while at the same time minimizing calculation effort that does not lead to significantly greater understanding of the policy questions in the work statement.

After trying several classification schemes and matrix descriptors, we have selected three important variables in characterizing a building's retrofit potential: structural type, which describes the buildings's envelope; mechanical system type, which describes the building's heating and cooling system; and usage type, which describes both the pattern and intensity of use.

Other descriptors were also examined, such as size and age. Age is a tempting variable to use in urban buildings, since census building data is available that characterizes buildings by age. This would be a useful public policy tool if retrofit potential could be predicted simply by age and structural/mechanical type.

Unfortunately, with a few notable exceptions, such as schools, age is not a very reliable descriptor of retrofit potential or applicability, and is not correlated with, but appears to be subsumed by variables which specify structural, mechanical, and usage types.

An assumption we have been asked to test is if a building's age is a strong indicator of the condition of its envelope and the potential ("applicability") of the building for mechanical system retrofit. Apparently not: the condition of the building does not vary directly with age, and the older the building, the greater the likelihood of major changes to the mechanical system. Newer is not necessarily better, of course; many older buildings may be more amenable to retrofit than their newer counterparts.

Most commercial buildings constructed in the last two decades are overlit, overventilated, and may use less efficient mechanical systems, such as terminal reheat; these inherent design constraints may limit conservation opportunities.

In short, it is not sufficient to know the age of the building; neither structure, physical condition, mechanical type nor usage can be predicted from age alone. In addition, age and only one of the other variables (structural, mechanical, or usage) cannot be used to predict the unknown variables. Reluctantly, we have discarded age as a matrix descriptor.

Size has a distinct effect on the cost and, in some cases, the physical applicability of retrofit measures. Although step functions in a cost of mechanical system retrofit occur with increasing size, the dominant characteristic of the relation between the cost of HVAC system retrofit and building size is one of increasing economy of scale.

This does not hold for the character of the equally strong relation between building size and cost of envelope retrofit. This relationship is characterized by increasing "steps" in cost of envelope retrofit as buildings increase in size (or more accurately, in height), dramatically increasing the cost of access to the location of the retrofit.

As a matrix descriptor, size does not determine structural or mechanical type unless coupled in some way with usage. As noted in the study Potential for Energy Technologies in Residential and Commercial Buildings (Arthur D. Little, November 1979, page 34), which compared field data for 200 buildings, there is no ecomomy of scale in energy consumption for larger buildings. Size is correlated with usage.

The four climate zones proportionally modify the savings derived from the measures, determining whether or not a measure will be cost-effective for a given location. In addition, with its global impact on fuel savings, the choice of climate zones dictates the physical applicablility of many of the measures, which is based on the probable occurrence of heating and cooling systems in different types of buildings.

4.1.2 Choice of Cities

The four cities chosen for retrofit measure computations are Buffalo, St. Louis, Memphis, and Tampa. The necessary weather data is available for all of them, passive solar data (from Los Alamos simulations) is available for all, and only Buffalo lacks solar data for F-chart (a modeling of solar fraction for active space heating and DHW). The Heating Degree Day and Cooling Degree Day is shown below (60° base temperature for both):

City	HDD	CDD
Buffalo	5,357	830
St. Louis	3,628	2,337
Memphis	2,528	2,750
Tampa	329	4,470

More detailed climatic data for the four cities is presented in Section 4.2. Criteria for the choice of these cities included broad geographic and climatic distribution, well-established urban building stock, moderate to large size, and correspondence with cities being used in other segments of the OTA Energy and the Cities project. Attention to older urban building stock and "OTA" cities accounts for the lack of a chosen city in the west. Attention to "OTA" cities accounts for the choice of Tampa although its building stock is relatively new.

4.1.3 Choice and Definition of Matrix Variables

The Structural Type, or building envelope variable, separates buildings into three groups with similar envelope retrofit potential.

The Mechanical System Type variable separates buildings into four groups to which families of mechanical systems measures can be applied.

The Usage Type variable sorts buildings into five groups that are similar in size as well as in pattern and intensity of use.

Detailed quantitative descriptors of the matrix variables are presented in section 4.2.

4.1.3.1 Structural Types

Three wall types have been chosen to cover the structural variety occurring among buildings in this country: Cavity-Wall, Bearing-Wall, and Clad-Wall. Roof assembly types are determined as a characteristic of the physical/usage types within each structural/mechanical type. All types are assumed to have full basements.

In more detail, the three types are:

1. Cavity Wall: All wood-frame walls fall into this category. The type is characterized by its accessiblity to blown-in retrofit wall insulation. Masonry cavity walls with the same accessibility would fit roughly into this category, but would tend to have a slightly higher heat transmission rate (U-value) than wood frame walls. This would make a wall insulation retrofit slightly more cost-effective, but would have little bearing on the cost-effectiveness of other measures.

   The following architectural elements are paired with cavity walls as being the likeliest structural combinations in actual buildings stock:

   Windows: Wood-framed double-hung windows are assumed for all usage types. This is typical of older urban wood-framed buildings, especially in the northeast. Many more recent wood-frame buildings have sliding or wood-framed casement windows. These would tend to have somewhat better thermal properties than the double-hung windows modeled for this type, which would slightly reduce the cost-effectiveness of both window retrofit measures and central heating/cooling plant efficiency retrofits (by reducing the base heating/cooling load).

   Roof: Wood roofs are the majority case in cavity-wall buildings, both wood-frame and masonry cavity. For detached single-family homes, a pitched wood roof over an uninsulated attic is assumed. This is a "worst case" assumption that will not hold true for many buildings in this category; a majority of attics may have some insulation in the colder climate zones. The presence of insulation could dramatically decrease the cost-effectiveness of an insulation retrofit, and would have some limited impact on heating/cooling plant measures, as described above.

For other wood-frame building types, a flat wooden roof is assumed, with a thin layer (1/2-inch to 3/4-inch) of fiber-type insulation board. This would be typical of much of the existing buildings stock, where relatively few older buildings have well-insulated roofs, but totally uninsulated roofs are rare. It does not account for buildings that have already undergone a roof insulation retrofit. In the colder climates, a considerable number of older flat-roofed buildings have had insulation added as part of the re-roofing process.

2. Masonry Bearing Wall: This category includes masonry construction, either solid or having a cavity, as in concrete block or double-brick walls, that is inaccessible to loose-fill insulation. The difference between solid and cavity is in this case significant only in that it alters the retrofit applicability for the Trombe wall passive solar measure. Therefore, the difference between solid and cavity masonry-bearing walls is treated as a footnote to the appropriate packages.

The following architectural elements are assumed with masonry-bearing walls:

Windows: A number of different window types are found in masonry-bearing structures, depending on size and usage type. Wood-frame double-hung windows are modeled for the single-family and small multifamily types. As discussed above for cavity walls, this would fit a majority of older building stock, but considerable variation would be found in buildings less than 30 years old. All commercial buildings in this category are modeled with metal-framed double-hung windows; this assumption has similar limitations. The large multifamily type is modeled with metal-framed residential casement windows. This is done on the assumption that there is some correlation between size and age; large multifamily structures, of eight stories or more, tend to date from the 1930s or later, when casement or similar window types would have been more common than double-hung.

Roof: A flat or slightly angled wood roof over an uninsulated crawl space is modeled for the attached single family (rowhouse) type. This is a "worst case" model, made on a similar basis to that of the detached single-family model. The basic structural model is representative of a majority of rowhouse stock, where rows of housing will commonly have a common roof line with a slight pitch from front to back and an accessible crawl space underneath. Accessibility to the space is assumed for application of loose-fill insulation.

All other usage types with masonry bearing walls are modeled with concrete deck flat roofs with a thin layer of original fiber-type deck insulation. The insulation is assumed on a basis similar to that discussed above. Many buildings of this type will have metal rather than concrete decks and a few will have wood decks. The difference in thermal properties is fairly minor if a thin (about 4 inch) concrete deck is assumed. Some buildings have thicker decks made of a semi-insulating lightweight masonry compound, which could differ considerably in thermal properties from either a steel deck or the type of concrete deck modeled here; these, however, would tend to occur in more recent building stock and would be a minority case.

Usage: A correlation between structural type and usage type is assumed for the single-family type only, where the detached home is modeled as cavity wall and the attached rowhouse is modeled as masonry-bearing wall. Wood-frame cavity wall rowhouses are rare, although masonry cavity wall rowhouses are somewhat more common. There are also a fairly large number of masonry bearing wall detached homes, particularly in the warmer climate zones. Therefore, making the assumption of a correlation between structural types and detached versus rowhouse eliminates a large number of cases, although the correlation is legitimate in itself. Masonry bearing-wall detached homes would be very similar to cavity-wall detached homes in overall retrofit potential, the major difference being in accessiblity for wall insulation.

3. Clad Wall: This is a combination of the original masonry- or metal-clad wall category and the curtain wall category. Both may have steel-frame or masonry construction with a non-bearing "skin" that may consist of prefab laminated walls, solid metal or masonry, and glass. Curtain wall, as previously defined, differs structurally from the masonry- or metal-clad wall only in the amount of glazing.

The clad wall is modeled as a skin of prefabricated masonry panels attached to metal framing, with an internal air space and no insulation. Obviously, given the multiplicity of existing clad-wall and curtain-wall types, this model is very limited in the proportion of actual building stock it represents. Creating additional structual types to account for a greater proportion of the total range would add greatly to the overall applicability of the results. Many clad walls and curtain walls, particularly in more recent construction, consist of pre-insulated sandwich panels mounted on the framework, which would have better thermal properties than the wall modeled here. A "worst case" assumption is made to maximize applicability to older building stock. The qualifications discussed above for buildings with better thermal properties than the base model would apply here.

The following architectural elements are assumed with clad walls:

Windows: Window type is more a function of usage type than structural type in this case. Metal-frame double-hung windows are assumed for the small multifamily. This would represent older building stock but would have limited applicability to more recent construction. Metal-framed commercial casement windows are modeled for both commercial usage types, and metal-framed residential casement for the large multifamily.

Roof: A flat concrete roof with a thin layer of fiber-type deck insulation is assumed for all clad wall structures. As discussed above for masonry bearing wall structures, many buildings in this category have metal roof decks; however, the difference in retrofit applicability or cost-effectiveness is minimal.

4. General Considerations - Structural Types

Heat losses and gains due to infiltration were calculated by the ASHRAE crack method, which requires assuming a particular quality of fit for windows and doors, as well as specifying the basic architectual type and glazing type. All buildings were assumed to have "average" fitting doors and windows, without weatherstripping and without storm windows. Obviously, this represents a gross simplification of the many conditions that actually exist. Many older buildings have been retrofitted with storm windows, particularly in the colder climates; this may apply to a majority in areas with climates like Buffalo's. Many buildings have also been at least partially weatherstripped. The calculated values for base case building energy use must be viewed in light of necessary assumptions such as these. A building with new storm windows and weatherstripped prime windows and doors could have a significantly lower heating demand than the base building with its "average" windows; this would consequently lower the cost-effectiveness of heating efficiency measures where the savings is proportional to overall heating demand. On the other hand, many older urban buildings, particularly those with wooden windows, have extreme deterioration of windows that would have the opposite effect on overall energy use. In view of the large spectrum of possibilities, it was considered best to choose an "average" value.

4.1.3.2 Mechanical System Types

The mechanical system typology was chosen to optimize the following combination of criteria:

- amount of calculation effort,
- total coverage of systems existing in the acutal building stock, and
- specific correlation with groups of retrofit measures.

As to total coverage, any reduction of mechanical systems to a small number of types is certain to lose some specificity in the measure matrix with ripple effects of generalization among the package matrix. Differences in fuel type will often require different measure treatments, even within the same mechanical system - such as gas- and oil-fired hydronic systems. As will be described later, these distinctions will be handled within the packages of retrofit measures chosen.

How many mechanical system and fuel supply type combinations need to be included to achieve reasonable coverage of the existing urban building stock? There is some census data available on distribution of heating systems in the residential sector. Residential Energy Consumption Survey: Characteristics of the Housing Stock and Households, 1978 (February, 1980) lists the distribution of various fuel and system types. The following table is derived from that data:

	Gas	Oil	Electricity	LP Gas
Warm air, ducts	32%	10%	6%	2%
Steam or hot water	7%	9%	-	-
Built-in electric	-	-	7%	-
Room heaters, with or without flue	7%	2%	-	-
Electric heat pump	-	-	2%	-

The fuel/system types listed account for 84% of the 76.6 million residential housing units. From this data, we have disregarded LP gas and heat pumps for the residential stock, and (by gross assumption), have extended those two deletions across all building types which we treat.

In addition, focusing on urban buildings allows the elimination of certain mechanical system types that are not well represented, with resulting simplification of the number of buildings types to be considered. Wood stoves, electric radiant, and radiant slab are not widely used, while buildings using electrical heat pumps have few, if any, mechanical system measures that apply.

Electrical heat pumps have only recently come into extensive use, require large capital investment, and therefore are not likely candidates for retrofit with newer models which are marginally more efficient. There are certain energy conservation practices that have limited applicability to heat pumps with electric resistance backup, such as large thermostat setbacks. Note that we are, however, considering "install electric heat pump" as a retrofit measure for electric resistance heating in some climate zones.

The mechanical system typology chosen is shown below. In order to develop building energy use profiles and to determine the specific applicability of energy conservation measures, it was necessary to choose one variety within each general system type as the base for the building model. The variety that was chosen for modeling is listed first within each system type, and the implications of that selection are discussed below.

Mechanical System Typology

Air

Single zone (single duct)

VAV, no reheat

Complex/Hybrid

Single duct, terminal reheat

Dual duct, with or without reheat

VAV, with reheat

Multizone

Water (Hydronic)

Hot water radiation

Steam radiation

Fan coil, 2 and 4 pipe

Induction, 2 and 4 pipe

Chilled water convector

Decentralized

Electric resistance baseboard radiation

Gas space heaters

Wall or window heating/cooling units

Air Systems: These systems provide heated and cooled air at a relatively constant temperature. For heating, the burner is cycled in response to the space thermostat, and the main fan is cycled in response to the burner and/or air stream temperature. Equipment is assumed to be oil-fired. Assuming oil rather than gas as the heating fuel has some impact on the applicability or cost-effectiveness of certain measures, discounting the different unit costs of the two fuels. These effects are discussed on a measure-by measure basis (see prose descriptions of measures).

All air systems are assumed to incorporate central cooling. This is modeled as a direct-expansion (DX) split system for the single family, small multifamily, and small commercial types, and as a chilled water system using a reciprocating chiller for the large commercial and large multifamily types. The distinction between types is drawn on the basis of the overall sizers of systems that would be required for the various usage types. The system is controlled by the compressor cycle in response to the space thermostat and the fan responding to the compressor and/or the supply air temperature. Air systems are assumed to handle outside air via a system of campers in the commercial usage types only.

Non-reheat VAV systems generally use less energy, for both heating and cooling, than simple single zone systems. Measures aimed at improving the energy efficiency of the central heating or cooling plants would be slightly less cost-effective for a VAV system than for a single zone system. However, VAV systems are a minority case in urban buildings in general, and are rare in the older buildings towards which the building models are oriented.

Water Systems: These systems have a water distribution system in common; piping measures that affect efficiency of distribution apply to this system type. The system is specifically modeled as a single-zone hot water baseboard radiation system, with a single water temperature set point. The boiler is cycled in response to the space thermostat, and the circulation pump responds to system water temperature. Gravity hot water systems would also be included in this category.

Water systems are assumed to have central heating only, with cooling provided by wall or window air conditioners, controlled on a room-by-room basis.

Buildings with steam radiation can be included in this category with little error; the principal difference is in the temperature at which heat is distributed in the building, which increases the cost-effectiveness of measures such as pipe insulation. The Modulating Aquastat measure, which deals specifically with regulation of water temperature, would not apply to steam systems. A somewhat analagous measure would be a steam pressure reset system. With those exceptions, most measures should apply equally to low-pressure steam and hot water systems.

Two-pipe fan coil and induction systems can also be included with relatively little error. The main difference is in the terminal heat distribution, which may be controlled by zone thermostats in fan coil and induction systems. This should not, however, have significant impact on the cost-effectiveness of most measures.

Four-pipe fan coil and induction systems, and chilled water convection systems are specifically excluded in that they include a central cooling system, which is not modeled for water systems. Heating-oriented measures, however, are roughly applicable to these system types. Measures oriented towards decentralized cooling would not be applicable. The cost-effectiveness of building envelope retrofits would be slightly altered due to the differenc in energy efficiency between central and decentralized cooling systems.

Complex Systems: All of these systems are a step up in complexity and have specific retrofit measures which apply. They have the common feature of either a "hot deck" and "cold deck" which is selectively mixed for zone temprature control, or a booster heat source to accomplish zone control. These systems are relatively rare in residential buildings, and are modeled for commercial buildings only.

This system type is specifically modeled as single-duct terminal reheat, with specifications as indicated in section 4.2.1. Cooling is provided by circulating cold air, at the temperature required by the zone with the greatest cooling load, to all zones. Air is then reheated to a particular zone's cooling requirements by a terminal coil; the reheat source is modeled as hot water or steam heated in a central oil-fired boiler and circulated to the terminal units. The energy consumption for direct gas-fired terminal units would be similar, although the cost would be less in accordance with the lower cost of gas versus oil. Heating is provided by circulating air to all zones at the temperature required by the zone with the least heating load; air temperature is boosted to the requirements of other zones at the reheat boxes. Many commercial buildings have internal zones with a net cooling requirement even in mid-winter; in such cases, the system return air (at approximately room temperature) is mixed with outside air to cool it to the temperature required by the internal zone with greatest heat gain. This is assumed to be the case in modeling the terminal reheat system.

Dual duct systems are similar to the single-duct terminal reheat, and most measures would apply equally to dual duct and terminal reheat systems. A principal difference is in the mode of heat distribution, which would make retrofit duct insulation more cost-effective in terms of absolute cost savings for dual duct systems than it is for terminal reheat systems (the greater amount of ductwork to be insulated in a dual duct system would be a mitigating factor).

Multizone and VAV/reheat systems are somewhat more energy-efficient than terminal reheat and dual duct. For that reason, overall system conversions would not be as cost-effective. The cost-effectiveness of building envelope measure would also be reduced relative to reheat or dual-duct systems, since the cost of the displaced energy requirement would be less.

Decentralized Systems: Few of the combustion-related mechanical systems measures apply to this category. The common feature of all decentralized systems is that no means of distributing energy around the building exists (with the exception of electrical wiring). It is assumed that the cost of retrofitting buildings now fitted with decentralized systems with central systems would be prohibitive, if it were structurally feasible at all, and that system-oriented retrofit measures are limited to those which improve the efficiency of decentralized equipment requiring only electricity.

The heating system in modeled as electrical resistance baseboard radiation, which cycles in response to room thermostats. Cooling is provided by separate window or wall air conditioners.

Buildings with all-electric wall units providing both heating and cooling would fit into this model in most respects, assuming the cooling portion operated at approximately the same efficiency as typical window or wall air conditioners. The principal difference would be in that most wall-mounted heating/cooling units handle a certain volume of outside air, which is sometimes true of window air conditioners, but does not apply at all to baseboard radiation. Many older units, or units not operated with energy conservation in mind, would tend to take in a much larger volume of outside air than is required for proper ventilation. The energy consumption of such systems would be much higher than a baseboard radiation system. This would make overall system conversion schemes relatively more cost-effective, especially in the excessive ventilation were inherent in the equipment and not subject to remedial maintenance. It would also increase the cost-effectiveness of building envelope measures where the system itself was not to be altered.

The model is of limited applicability to gas space heaters. Such systems require a gas distribution system, which is assumed not to exist. Where a gas piping system does exist, measures such as high-efficiency room-sized pulse boilers are worth considering. However, the incidence of such systems was considered too low to justify treating as a separate measure. The efficiency of many gas space heaters is sufficiently low that the overall energy cost may approach that of electric resistance. However, the applicability of savings calculated for building envelope measures would depend on the efficiency and energy cost of space heaters in a particular building that was under consideration.

General Considerations - Systems

System Efficiency: The seasonal heating efficiencies used to calculate the base model energy use are presented in detail in section 3.1.2. The seasonal efficiency of a system is the ratio of the building's net total demand for heating energy over the course of the heating season (envelope loads plus ventilation and infiltration loads minus internal and solar heat gains), divided by the total volume of heating fuel consumed. The remaining energy is "lost" through a combination of unburned fuel and still-hot combustion gases going up the flue, heat being lost by the system while the burner is cycled off (standby losses), and heat being radiated away by a furnace or boiler jacket and through piping or ductwork, only some of which remains in the building and contributes to meeting the heating load. Terminal distribution and perceived comfort levels also influence the effective efficiency of a system. For example, a building heated by large upright cast-iron radiators mounted directly next to uninsulated walls will require more fuel than an otherwise identical building heated by properly placed fin-tube baseboard radiators, due to the heat radiated directly through the walls that never contributes to satisfying the heating load or improving the comfort level. Buildings with "hot spots" and "cold spots" due to distribution problems also use more energy.

The base case heating efficiencies used in developing the building energy profiles are based on laboratory results, as described in Section 3.1.2. Statistical information on system efficiencies is limited, and these results are applicable primarily to oil-fired hydronic equipment. The implications of this limitation are discussed as they apply to individual measures in the measure prose descriptions. A principal limitation is that the efficiency measurements, having been obtained under laboratory conditions, do not account for distribution losses. On this basis, fuel consumption would tend to be underestimated. However, other aspects of the calculation method tend to overestimate the heating load. Therefore, there is a tendency for the net error to be balanced out.

Zoning: All systems are modeled as single-zone, inasmuch as a single temperature setpoint is assumed for the entire building at any given time. This represents somewhat of an oversimplification, particularly in the case of complex systems, which are multi-zone systems by definition. The single-zone assumption makes little difference in the building energy profile or in the application of measures except for complex systems, where it tends to overestimate base energy use by assuming that reheat is applied to all zones where in fact it generally would not. This means that the actual cost-effectiveness of system conversions and building envelope measures is somewhat less than calculated.

Controls and Setpoints: For all building types, it is assumed that an inside temperature of 65° is maintained throughout the heating season, and 78° throughout the cooling season. It is further assumed that heating and cooling controls are fully operative, and that the heating and cooling seasons are adjacent. This represents several simplifications of actual situations:

1. Since it was necessary to choose one particular set of temperatures, it was considered best to choose temperatures consistent with current energy conservation guidelines. Variations from these temperatures are considerable in real buildings, whether by deliberate setting or by failure of the controls to properly regulate the temperature. Variations for the heating energy estimate of +/- 20% are conceivable from thermostat settings alone.

2. The assumption that temperatures are maintained 24 hours per day is also of limited applicability. While this may have been common 10 years ago, many building operators have already implemented temperature setbacks, either by installing setback thermostats or by manual control, particularly in commercial buildings. Prior implementation could reduce the energy use profile by 10-15%, reducing the base for savings in heating and cooling efficiency measures.

3. It is assumed that the system is in either heating mode or cooling mode all of the time, but that there is no "zero energy" interval in the spring and fall when neither is required or used. This does not have a major impact on the base case energy profiles, which are primarily based on average climatic data and are not heavily dependent on the length of the heating and cooling seasons. However, a number of measures yield savings which are in effect during a particular season and are to some degree proportional to the length of the season; the assumption that the systems are in operation throughout the year may overestimate savings for some measures.

Cooling: It is assumed that mechanical cooling is used in all building types and all climate zones, and that a building's entire cooling load is satisfied by the system. This tends to overestimate overall energy loads in two respects. First, many buildings are not cooled at all, particularly single-family and small multifamily buildings in the cooler climates. Cooling of older small multifamily buildings is, in fact, a minority case in most northern cities. Not only are cooling measures, and packages containing cooling measures, inapplicable to buildings without cooling, but the cost-effectiveness of building envelope measures is reduced as well (however, the heating portion of building envelope savings is much more significant than the cooling portion in the colder climates). Second, many buildings are partially cooled, particularly those in the Water and Decentralized system categories with room-by-room cooling. This would greatly reduce, although not eliminate, the savings to be realized from cooling-oriented measures and somewhat reduce the cost-effectiveness of building envelope measures. The difference in envelope savings is probably, however, insignificant in colder climates.

We feel that these categories divide well into families of retrofit measures, grouped primarily around distribution type. Notice that true combinations of dissimilar systems have been omitted, due to an excessive number of possible pairs of systems. Thus, many combinations are treated as separate systems; an owner with an oil-fired warm air system in one part of the building and gas-fired forced hot water will look them independently, as well as referring to their individual measures descriptions. However, cost and savings estimates calculated for this report are strictly applicable only to buildings services by a single system. The are approximately appliacable to multiple-system buildings where the results are adjusted to reflect the percentage of conditioned space served by each system.

4.1.3.3 Usage Types

The third variable necessary to describing the retrofit potential is the usage type, which describes the main activity in the building and load profile. There is little agreement in the literature on classification of building types, and insufficient national building data. In addition to usage types, size must be considered as a factor.

The BEPS Phase One/Base Data (January 12, 1978) is based on predicted performance of buildings being constructed in 1975 and 1976. Lack of categorization by size, and the study's exclusive focus on new buildings, limits the usefulness of this categorization for our purposes.

The Syska and Hennessy/Tishman Research Corporation report, Energy Conservation in Existing Office Buildings, chose New York City buildings to provide a statistical sample, thus blurring differences by size.

The Arthur D. Little study, Potential Energy Technologies in Residential and Commercial Buildings, November 1979, established unit demands for five varieties of single family and multifamily housing and five other building types: office buildings, retail establishments, schools, hospitals, and a catch-all category which includes hotels, motels, dormitories, amusement and recreational facilities, and religious buildings. The last category is assumed to have consumption equivalent to retail establishments.

Noting the lack of unanimity as to either the energy consumption of buildings or the way in which they should be grouped to reflect similar usage, we have used a combination of physical and usage characteristics to reduce the number of models to the minimum that will still reasonably represent the building stock. Three physical models which represent a total of five usage types are proposed for purposes of calculating sensitivity to retrofit measures. The three models are:

1. A two-story, 2,000 square foot building representing single-family detached, single-family attached, and rowhouse residential units.

2. A three-story, 15,000 square foot building representing small multifamily, low-rise, and motel buildings, as well as small office, small retail, and elementary schools.

3. A eight-story, 100,000 square foot building that represents large office, large retail, and high-rise apartment buildings.

The five physical/usage types are:

1. Single family, simulating all the first physical types, assuming 20 gallons hot water use per person per day, as assumed in the Arthur D. Little study, normal residential lighting levels, and round-the-clock occupancy.

2. The second and third physical usage types use the second physical model, the three-story building. The second P/U type uses residential DHW, lighting, and occupancy loads to simulate small multifamily and low rise buildings. This would represent a 15 unit building with housing units of 1,000 square feet each.

Motels were originally considered for this type, but have characteristics sufficiently different from other buildings here that this category does not fairly represent them. Motels are different in that their lighting, domestic hot water, heating, and cooling loads are all significantly higher than any other group in this category. Motels are currently not treated, although the reader may responsibly assume that because of the increased intensity of loads, any retrofit measure in this physical/usage type will be more cost-effective than the value displayed in the appropriate matrix.

3. The third P/U type uses the same size building as 2 above, but assumes lower DHW loads, higher lighting and occupancy loads, and larger areas of glazing throughout. In addition, usage is assumed to be a ten- to twelve-hour day. This P/U type represents small office and small retail buildings.

This category is the most logical in which to place elementary schools as well, but because of their higher density of use, higher domestic hot water loads, and shorter periods of occupancy, they have temporarily been omitted. The direction of variation in cost-effectiveness may be responsibly inferred from the description of the nature of variation given above.

4, 5. The fourth and fifth P/U types are based on the third physical type, the eight-story building. The fourth type uses lower DHW, higher lighting, higher occupancy loads, and larger glazing areas than residential use and represents large office and large retail buildings. The fifth type uses residential levels for lighting, DHW, and occupancy to represent high rise and other large apartment buildings.

Hotels logically fall within this category, but because of variations in their use similar to those described in category 2 above, they are omitted.

A summary of these physical/usage calculation models is shown below:

Physical/Usage Types

Type	Name	Usages	Physical Type
1	Single Family	single family detached single family attached rowhouse	1
2	Small Multifamily	small multifamily low rise apartment	2
3	Small Commercial	small office/commercial small rental (elmentary school)	2
4	Large Commercial	large office/commercial large retail	3
5	Large Multifamily	large apartment block high-rise apartment	3

Section D: Detailed Parameters of the Building Models

Parameters used in the building model specifications are presented here in a straightforward, if somewhat cryptic, fashion. Abbreviations used are as follows:

P/U 1 = Physical Use Type
Small House (2000 sq.ft.)

P/U 2 = Physical Use Type
Medium Multi-Family Building (18 units, 15,000 sq.ft.)

P/U 3 = Physical Use Type
Medium Commercial Building (15,000 sq.ft.)

P/U 4 = Physical Use Type
Large Commercial Building (100,000 sq.ft.)

P/U 5 = Physical Use Type
Large Multi-Family Building (100,000 sq.ft.)

AIR = Air Heating and Cooling System

H_2O = Water or Steam Heating System
(with window air conditioners)

DEC = Decentralized Heating and Cooling System

COM = Complex Heating and Cooling System

The structural codes used for each physical usage type are:

A: Cavity Wall

B: Masonry Wall

C: Clad Wall.

4.2.1 Detailed Building Assumptions: Architecture, Occupancy, HVAC, and Climate

Notes to Mechanical Parameter Matrix

1. Applies to electric resistance heating.

2. Ventilation air volume sized at 7.5 CFM per person, based on ventilation codes that were in effect when most older building systems were installed.

3. Ventilation volume for buildings without central air systems is the estimated exhaust capacity that would be installed to meet code requirements for toilet rooms. Where outside air make-up is not provided, exhausted air would tend to be replaced by infiltration, incurring an additional load on heatng and cooling systems roughly equivalent to that of the same volume of ventilation air.

4. Void.

5. Void.

6. Peak enthalpy range is based on return air conditions of 75°F DB and 50% R.H., and supply air conditions of 55° DB, 90% R.H.

7. Seasonal heating efficiency of non-electric heating plant is a function of seasonal operating hours (as a proportions of maximum possible operation). See supplementary tables and energy profile equations.

8. Void.

9. C.O.P. values apply to window or wall A/C units.

MECHANICAL PARAMETER MATRIX

		P/U # 1			P/U # 2		
	MECH. SYSTEM TYPE →	AIR	H_2O	DEC	AIR	H_2O	DEC
HEATING	EFFICIENCY, STEADY-STATE	.70	.70	.95[1]	.75	.75	.95[1]
	" ", SEASONAL	NA[7]	NA[7]	.90[1]	NA[7]	NA[7]	.90[1]
	AIR ΔT, °F	70	NA	NA	70	NA	NA
	AIR SUPPLY TEMP., °F	135	NA	NA	135	NA	NA
	WATER ΔT, °F	NA	20	NA	NA	20	NA
	WATER SUPPLY TEMP. °F	NA	180	NA	NA	180	NA
	VENTILATION CFM[2]	N.A.	NA	NA	375	N.A.	N.A.
	VENTILATION HRS/WK	N.A.	NA	NA	168	N.A.	N.A.
	REHEAT BASE AIR TEMP.	NA	NA	NA	NA	NA	NA
	PIPE LOSS REDUCTION, BTUH	NA	6320	NA	NA	38,105	NA
COOLING	COOLING SYS. COP, INST.	2.34	1.8[9]	1.8[9]	2.52	1.8[9]	1.8[9]
	" " ", SEAS.	2.03	1.52[9]	1.52[9]	2.22	1.52[9]	1.52[9]
	NEW EQUIP. COP, SEAS.	2.27	2.27	2.27	2.47	2.27	2.27
	CHILLED H_2O TEMP.	NA	NA	NA	45	45	NA
	" " ΔT	NA	NA	NA	10	10	NA
	AIR ΔT/SUPPLY T	20/55	=	=	=	=	=
	AIR ΔH, BTU/LB[6]	6.0	=	=	=	=	=
	REHEAT BASE AIR TEMP.	NA	NA	NA	NA	NA	NA

MECHANICAL PARAMETER MATRIX, CONT.

	P/U #3				P/U #4				P/U #5			
	AIR	H2O	DEC	COM	AIR	H2O	DEC	COM	AIR	H2O	DEC	COM
	.75	.75	.95[1]	.22 to .56	.75	.75	.95[1]	.22 to .56	.75	.75	.95[1]	.22 to .56
	N.A.[7]	NA[7]	.90[1]	NA[7]	NA[7]	NA[7]	.90[1]	NA[7]	NA[7]	NA[7]	.90[1]	NA[7]
	70	NA	NA	VAR.	70	NA	NA	VAR.	70	NA	NA	VAR.
	135	NA	NA	VAR.	135	NA	NA	VAR.	135	NA	NA	VAR.
	NA	20	NA	NA	NA	30	NA	NA	NA	30	NA	NA
	NA	180	NA	NA	NA	200	NA	NA	NA	200	NA	NA
	1125	720[3]	720[3]	1125	7500	1680[3]	1680[3]	7500	6000	3525[3]	3525[3]	6000
	60	60	60	60	60	60	60	60	168	168	168	168
	N.A.	N.A.	N.A.	60	N.A	NA	NA	60	NA	NA	NA	NA
	NA	38105	NA	NA	NA	155370	NA	NA	NA	155370	NA	NA
	2.6	1.8[9]	1.8	2.6	2.6	1.8[9]	1.8	2.6	2.6	1.8[9]	1.8	2.6
	2.26	1.52[9]	1.52	2.26	2.26	1.52[9]	1.52	2.26	2.26	1.52[9]	1.52	2.26
	2.52	2.27	2.27	2.52	2.52	2.27	2.27	2.52	2.52	2.27	2.27	2.52
	45	45	NA	45	45	45	NA	45	45	45	NA	45
	10	10	NA	10	10	10	NA	10	10	10	NA	10
	20/55	=	=	VAR.	20/55	=	=	VAR.	20/55	=	=	=
	6.0	=	=	VAR.	6.0	=	=	VAR.	6.0	=	=	=
	NA	NA	NA	55	NA	NA	NA	55	NA	NA	NA	55

LIGHTING AND EQUIPMENT

PARAMETER	ABBREV.	P/U 1	P/U 2	P/U 3	P/U 4	P/U 5
MAX. KW, ROOMS, INCANDESCENT	KW, RM, I	1.4	15.0	121.4	740.6	100.0
" " " , FLUORESCENT	KW, RM, F	N.A.	N.A.	31.4	191.3	N.A.
MAX. KW, CORRIDORS, INCAN.	KW, COR, I	N.A.	2.26	5.04	23.3	23.1
" " " ", FLUOR.	KW, COR, F	N.A.	0.62	1.31	6.0	6.3
EQUIV. FULL USE HOURS/WK, RMS	EQ. HR, RM	38.2	38.2	60	60	38.2
" " " ", CORR.	EQ. HR, COR	N.A.	168	87	87	168
WEEKLY EQUIP. HEAT, 10^6 BTU	EQUIP. H.G.	0.32	3.6	0.72	3.59	21.9

OCCUPANCY

PARAMETER	ABBREV.	P/U 1	P/U 2	P/U 3	P/U 4	P/U 5
MAX. OCCUPANCY	OCC, MAX	4	50	150	1000	330
EQUIV. FULL OCCUPANCY HR/WK	EQ. HR/WK	134	134	44	44	134
TOTAL WEEKLY OPERATING HRS.	OP. HR.	168	168	60	60	168
WINTER TEMP., OCCUPIED		68	68	65	65	68
" " , UNOCCUPIED		N.A.	N.A.	65	65	N.A.
SUMMER TEMP, OCCUPIED		78	78	78	78	78

DOMESTIC HOT WATER MATRIX

P/U TYPE →	1	2	3	4	5
PEAK HOUR USE, GAL.	12	180	60	400	1000
EQUIV. FULL HRS/WK.	24.5	24.5	17.5	17.5	29.4
AVG. WEEK USE, GAL.	294	4410	1050	7000	29400
HEATER CAPACITY, MBH[B]	12	169	35	230	938
STORAGE VOLUME, GAL.	30	400	90	600	8000
STOR. TANK U-VALUE	.301	1.45	=	=	=
SUPPLY TEMP, °F	140	140	105	105	140
EFFICIENCY, STEADY-ST.[A]	.75	=	=	=	=
" " DHWSE, SEASONAL[D]	.47	.48	.33	.34	.54
OVERALL % ON-TIME[C]	10.9	11.6	8.2	8.3	14.0
DHWSEVD SEAS. EFFIC. W/VENT DAMPER	.62	.62	.57	.57	.65

A. EFFIC. given for separate direct-fired heater

B. Rated output @ 25% oversize

C. % ON-TIME = $[\text{WEEKLY GAL.} \times 8.34 \times 52 \times (\text{SUPPLY T} - 50 \overset{\times 10^{-3}}{)}]/(\overset{\text{MBH}}{\text{CAPACITY}} \times 24 \times 365$

$$= \frac{\text{WEEKLY GAL} \times (\text{SUPPLY T} - 50)}{\text{MBH}} \times 4.951 \times 10^{-5}$$

D. BASED ON STUDY FOR SMALL OIL-FIRED WATER BOILERS, BNL

Guide to Architectural Descriptive Code

Wall Types

A. Wood cavity wall, 4-inch studs, uninsulated; exterior wood shingles, interior plaster or sheetrock.

B. Masonry bearing, 8-inch common brick, uninsulated.

C. Clad wall, masonry on stud or curtain wall.

Roof Types

1. Wood, pitched, over unheated attic, uninsulated.
2. Wood deck, flat, 1/2 - 3/4-inch insulation board.
3. Wood deck, flat or slightly angled, over crawl space.
4. Concrete deck, flat, 1/2 - 3/4-inch insulation board.

Window Types

1. Double-hung, wood frame, single glazed.
2. Double-hung, metal frame, single glazed.
3. Commercial casement, metal frame, single glazed, 25% operable area.
4. Residential casement, metal frame, single glazed, 35% operable area.

Door Types

1. Solid hardwood.
2. Glass, aluminum frame.

Shape and Exposure

1. Rectangular, detached.
2. Rectangular, attached 2 sides.
3. Courtyard, detached.

ARCHITECTURAL PARAMETER MATRIX

P/U TYPE →	1		2			3			4		5	
STRUCTURAL CODE →	A	B	A	B	C	A	B	C	B	C	B	C
WALL U-VALUE	.306	.257	.306	.257	.288	.306	.257	.288	.257	.288	.257	.288
WALL AREA, FT^2	1820	880	7875	=	=	7200	=	=	25,200		40,800	
ROOF U	.21	.21	.159	.211	.211	.159	.211	=	=	=	=	=
ROOF AREA	1000	=	5000	=	=	=	=	=	12,500		=	=
WINDOW U	.961*	=	=	=	1.13	.961*	1.13	=	=	=	=	=
WINDOW AREA	260	120	1125	=	=	1800	=	=	10,800		7200	=
FLOOR $\frac{\text{BTU}}{\text{HR-L.F.-}^\circ\text{F}}$	1.05	=	=	=	=	=	=	=	=	=	=	=
FLOOR PERIM., LF	130	44	300	=	=	=	=	=	450	=	600	=
WINDOW CRACK	370	170	1590	=	=	2550	=	900	15300	5400	5070	=
DOOR CRACK, FT.	40	=	80	=	=	=	=	=	160	=	120	=
DOOR U	.57	=	1.13	=	=	=	=	=	=	=	=	=
DOOR AREA	42	=	96	=	=	=	=	=	192	=	144	=
BLDG. HEIGHT	20	=	30	=	=	=	=	=	80	=	=	=
DESCRIPTIVE CODE (SEE ATTACHED GUIDE)												
WALL TYPES	A	B	A	B	C	A	B	C	B	C	B	C
ROOF TYPES	1	3	2	4	4	2	4	4	4	4	4	4
WINDOW TYPES	1	1	1	1	2	1	2	3	2	3	4	4
DOOR TYPES	1	1	2	2	2	2	2	2	2	2	2	2
SHAPE/EXPOS.	1	2	1	1	1	1	1	1	1	1	3	3

Notes to Climate Matrices

A. Based on 65° indoor.

B. Based on 75° indoor.

C. Based on 75°, 50% R.H.

D. Insolation at 3:00 p.m., July 23.

E. Value for 3:00 p.m.

F. Assumes roof weight = 40 lb./SF.

G. Assumes wall weight = 80 lb./SF.

H. Includes % of sunshine factors plus .80 factor for dirt, shading, etc.

J. Calculated from temperature bin data for frequency of MCWB occurences.

K. Source: Energy Conservation with Comfort, Honeywell (13).

L. Source: RCS manual (18).

M. Source: Carrier manual I, interpolated with average wind data (8a).

CLIMATE MATRIX - 1

		BUF.	ST. L.	MEM.	TAM.
	DESIGN CONDITIONS				
3	WINTER ΔT Ⓐ	70	65	52	29
4	SUMMER ΔT Ⓑ	18	20	20	20
5	SUMMER ΔH Ⓒ $\frac{BTU}{LB}$	8.4	13.2	13.2	13.2
7	PEAK SOLAR $\frac{BTU}{HR\text{-}SF}$ Ⓓ, S	33	26	20	14
8	" ", N	13	13	13	14
9	" ", E	13	13	13	13
10	" ", W	143	144	145	145
	DESIGN, EQUIV ΔT Ⓔ				
12	" " ROOF Ⓕ	33	33	33	34
13	" " WALL Ⓖ, S	20	20	15	11
14	" " ", N	5	5	5	5
15	" " ", E	16	16	16	16
16	" " ", W	14	14	14	14
17	WINTER GROUND T	53	57	61	67
19	HEATING SEAS., DAYS	240	185	180	90
20	COOLING SEAS., DAYS	125	180	185	275
	WIND SPEED				
24	AVERAGE, WINTER	13.2	10.5	10.3	9.3
25	" ", SUMMER	10.9	8.7	8.3	8.7
26	MAXIMUM, WINTER	70	60	46	50
27	" ", SUMMER	59	48	40	58

CLIMATE MATRIX - 2

		BUF.	ST. L.	MEM.	TAM.
	DEGREE - DAYS				
30	HTNG., 60° BASE, TOTAL	5357	3628	2528	329
31	" , " " , DAY	1458	1007	658	60
32	" , 55° BASE, NIGHT	3138	2107	1399	179
33	CLNG., 60° BASE, TOTAL	830	2337	2750	4470
34	" , 50° BASE, "	1946	3936	4225	7451
35	AVG. TEMP., HTNG. SEAS.	37.8	41.6	48.6	61.3
36	" " , COOLING "	65.6	71.0	74.7	75.9
	SEASONAL SOLAR HG Ⓗ BTU/SF				
39	HTNG. SEAS., S	72557	81140	62206	17420
40	" " , N	9671	7940	5650	1406
41	" " , E, W	45460	40475	28476	6578
	COOLING SEAS., S	26657	41192	40940	50213
	" " , N	10030	13656	16692	20432
	" " , E, W	42736	59180	70001	87694
	% SUNSHINE, HTNG.	42.8	52.4	53.4	63.7
	% SUNSHINE, CLNG.	65.9	67.0	71.1	67.7
	MECHANICAL PARAM.				
49	EVAP. COOLING POTEN. Ⓙ BTU/CFM/YR	25980	25853	16527	18875
50	OA ECONOMIZER POT. Ⓚ HONEYW'L K-FACTOR	13.376	12.934	13.553	9.479
51	HEAT PUMP COP Ⓛ HEATING SEASON	1.307	1.550	1.770	2.15
	COND. COIL SPRAY SAV.	.166 RECIP	175	.162	.153
	(CCSS)	[illegible]	[illegible]	.044	[illegible]

CLIMATE MATRIX - 3

INFILTRATION LOAD Ⓜ FACTORS - CFM/LIN. FT.	BUF.		ST. L.		MEM.		TAM.		APPLICABILITY
	W	S	W	S	W	S	W	S	
1 Wood, Double-hung, WS	.34	.25	.24	.18	.23	.17	.20	.18	1, 2A, 2B, 3A
2 " " " No WS	.54	.40	.38	.29	.37	.27	.32	.29	
3 Wood, loose, w/storm, WS	.24	.18	.17	.13	.17	.12	.14	.13	
4 " " " NO WS	.80	.63	.61	.48	.59	.45	.52	.48	
5 Metal sash 2-hung, WS	.45	.38	.34	.26	.33	.25	.29	.26	3B 4B
6 " " ", NO WS	1.07	.86	.83	.66	.81	.63	.72	.66	
7 Resid. casement, looser	.75	.59	.56	.45	.55	.43	.49	.45	2C 58,C
8 Arch. projected "	1.25	.98	.93	.29	.91	.69	.79	.29	3C 4C
GLASS DOOR, Avg.	12.6	10.7	10.4	8.65	10.2	8.23	9.27	8.65	2-5 ALL
WOOD DOOR, loose, no WS	3.20	2.55	2.44	1.94	2.38	1.82	2.10	1.94	1 ALL
" ", tight, WS	.79	.65	.63	.56	.62	.55	.58	.56	

4.2.2 Building Energy Use Modeling: Equations and Assumptions

The parameters generated in Phase I are used as the base for developing a numerical profile of the annual energy use for each SMP/U type in each climate zone. A Peak Load Profile is used to determine the sizing for heating and cooling equipment. The Seasonal Load Profile determines heating and cooling loads on a yearly basis. These are used together to determine the average seasonal operating hours of equipment, which determines the parameters for the Energy Use Profile. Finally, the annual fuel energy use for each SMP/U and climate zone can be calculated. Results of these calculations are not presented here, but are available on file.

Format

Equations are presented as they were written for programmed calculation. Abbreviations follow the description of the parameter. Suffixes "S" and "W" are used to label whether the parameter refers to summer (cooling) or winter (heating) energy use.

Peak Load Profile

Peak Solar Gain, Summer

PHGH = (A, Wi, SO x I, SO) + (A, Wi, NO x I, NO) + (A, WI, E x I, E) +
(A, Wi, W x I, W)

Where A, Wi = window area; I = peak insolation (see climate matrix), and suffixes SO, NO, E, W refer to directions. Peak insolation is determined for 3:00 p.m. on July 23.

Peak Internal Heat Gain

PIGH = (OCC, MAX x 400) + (3,413 x (KW, RM, I + KW, COR, I)) +
(EQUIP. H.G./168)

Refer to lighting and occupancy matrices.

Peak Ventilation Load

PVL, S, W = VCFM x DESIGNΔ T, S, W x 1.08

Where VCFM = Ventilation volume, cubic feet per minute.

Infiltration Volume (CFM)

ICFM, W = ((CL, Wi x F, Wi, W) + (CL, D x F, D, W)) x 0.4

ICFM, S = ((CL, Wi x F, Wi, S) + (CL, D x F, D, S)) x 0.4

Where CL, Wi = window crack length; CL, D = door crack length; F, Wi = window infilration load factor (summer and winter); F, D = door infiltration load factor. The infiltration load factors given in the climate matrix are based on average seasonal wind speeds, yielding average infiltration volume.

Peak Infiltration Load

PINL, S, W = ICFM, S, W x 1.08 x DESIGN DT, S, W x .75 x R, WIND, S, W

Where R, WIND = ratio of mean maximum wind speed to average wind speed.

Peak Heating Load

PHL + (BLDG. UA x DESIGN DT, W) x PINL, W + PVL, W

Where BLDG. UA = Building envelope heat transmission coefficient, Btu/hr. - °F, based on parameters in the Architectural matrix.

Peak Cooling Load

PCL + (BLDG. UA x DESIGN DT, S) + PINL, S + PVL, S + PIHG + PSHG

Air System Total CFM

TSCFM, S = PCL/(1.08 x 20°) = PCL/21.6

TSCFM, W = PHL/(1.08 x 65°) = PHL/70.2

It is assumed that building systems are sized according to TSCFM, S.

Seasonal Load Profile

Seasonal Solar Heat Gain (SSHG, W and SSHG, S)

Method similar to that used in calculating PSGH, using seasonal solar gain factors from the climate matrix.

Seasonal Occupant Heat Gain

OHG, S = (OCC, MAX x 400) x (EQ. HR/wk) x (LCS/7)

OHG, W = (OCC, MAX x 400) x (EQ. HR/wk) x (LHS/7)

Where LCS, LHS = lengths of cooling and heating seasons, days.

Light and Equipment Heat Gain

LHG, S, W = ((((KW, RM, I x EQ. HR, RM) + (KW, COR, I x EQ. HR, COR)) x 3,413) + EQUIP. HG) x LCS, LHS

Infiltration Load

INL, S = ICFM, S x 1.08 x 24 x CDD

INL, W = ICFM, W x 1.08 x 24 x HDD

Where CDD, HDD = seasonal cooling and heating degree-days, base 60.

Ventilation Load

SVL, S, W = VCFM x 1.08 ((OP. HR/wk)/168) x 24 x CDD, HDD

Where OP. HR/wk = weekly ventilation operating hours.

Building Envelope Load

EL, S, W = BLDG. UA x 24 x CDD, HDD

Seasonal Heating Load

SHL = EL, W + SVL, W + INL, W - OHG, W - LHG, W - SSHG, W

Seasonal Cooling Load

SCL = EL, S + SVL, S + INL, S + OHG, S + LHG, S + SSHG, S

Seasonal Heating Load, Reheat System

RESHL, W = SHL + (((207.3 X TSCFM) - (74.1 x VCFM)) x LHS)

RESHL, S = 46.3 x TSCFM x LCS

The parameters in these equations were developed according to the reheat system base temperatures and operating ranges given in the Mechanial Parameter Matrix.

Heating and Cooling Percentage On-Time

HPOT = SHL/(PHL x 1.25 x 24 x LHS)

CPUT = SCL/(PCL x 1.25 x 24 x LCS)

It is assumed that systems are sized about 25% above peak load. HPOT is used as the base for determinal seasonal heating efficiency SHE.

Heating Percentage On-Time, Reheat System

REHPOT, S = RESHL, S/(PHL x 1.25 x 24 x LCS)

REHPOT, W = RESHL, W/(PHL x 1.25 x 24 x LHS)

Summer Boiler Percentage On-Time for DHW (Tankless Coil)

SBPOT = (.045 x DHW GAL/wk x (T, USE - 60))/PHL

Where T, USE = hot water supply temperature.

Energy Use Profile

The seasonal energy use of systems, particularly heating systems, is a function of the load and of the seasonal operating efficiency of the system. Seasonal efficiency is a function of equipment type and condition (determining steady-state efficiency) and seasonal percentage operating time. A study performed by Brookhaven National Laboratories (see item 7, Bibliography) has produced seasonal operating efficiencies of various types of heating equipment as a function of on-time. This data was used to generate parameters for the seasonal heating efficiency (SHE) equation, which was used in calculating building energy use and is used in many energy savings algorithms. The equation parameters are given on the following page, and the efficiencies calculated for various systems and climate zones on the next three pages.

BOILER EFFICIENCY MATRIX

FORM OF EQUATION: SHE = A + B(HPOT − C)

where HPOT = Heating % on-time

Substitute SBPOT for summer DHW efficiency

CASE I: Single-pass, vertical fire-tube, dry-base steel boiler

CASE II: Similar equip., with retention-head burner

CASE III: Wet-base, 2-pass, horiz. fire-tube steel boiler, induced draft burner

CASE IV: Case I with stack economizer ("Maxi-heat")

CASE V: Case I with mechanical vent damper

	I			II		III		IV		V	
RANGE, % ON-TIME	A	B	C	A	B	A	B	A	B	A	B
① 5% - 10%	.30	3.2	.05	.38	4.0	.55	3.0	.40	4.0	.51	2.0
② 10% - 12.5%	.46	1.6	.10	.58	2.0	.70	1.2	.60	2.4	.61	0.8
③ 12.5% - 15%	.50	2.4	.125			.73	0.8	.66	1.6	.63	1.2
④ 15% - 20%	.56	1.0	.15	.68	0.4	.75	0.6	.70	0.6	.66	0.6
20% - 25%	.61	0.8	.20	.70	0.6	.78	0.2	.73	0.8	.69	0.2
25% - 60%	.65	.086	.25	.73	.057	.79	.057	.77	.114	.70	.029
	(68)			(75)		(81)		(81)		(71)	

EFFICIENCIES -1

BASE CASE (TYPE I)

	BUF	STIL	WEM	TAM
P/U 1A	.61	.595	.567	.65
1B	.562	.524	.463	.65
2A	.574	.536	.542	.65
2B	.492	.514	.511	.63
2C	.502	.541	.454	.65
3A	.538	.576	.517	.65
3B	.546	.517	.481	.57
3C	.55	.519	.481	.58
4B	.564	.522	.46	.51
4C	.571	.524	.438	.52
5B	.56	.474	.30	.62
5C	.568	.489	.30	.65

RETENTION-HEAD BURNER (II)

	BUF	STIL	WEM	TAM
P/U 1A	.70	.694	.683	.38
1B	.681	.65	.584	
2A	.686	.66	.536	
2B	.62	.642	.516	
2C	.582	.664	.572	
3A	.612	.686	.644	
3B	.61	.644	.606	
3C	.622	.646	.606	
4B	.682	.648	.58	
4C	.684	.65	.552	
5B	.68	.598	.38	
5C	.683	.616	.38	

REHEAT SYSTEM, BASE CASE

SHERA = .65, all types

TYPE II SHERA =	.73
III	.79
IV	.77
V	.70

EFFICIENCIES - 2

	NEW BOILER (II)				STACK RECLAIM (IV)				VENT DAMPER (V)			
	B	STL	M	T	B	STL	M	T	B	STL	M	T
?/U 1A	.78	.771	.754	.55	.73	.721	.704	.40	.69	.681	.664	.51
1B	.751	.738	.702		.701	.676	.605		.661	.642	.612	
2A	.758	.742	.667		.708	.684	556		.668	.648	.588	
2B	.724	.735	.652		.648	.670	536		.626	.637	.578	
2C	.731	.744	.694		.662	.687	592		.631	.65	.606	
3A	.743	.76	.736		.686	.71	671		.649	.67	.638	
3B	.745	.736	.716		.690	.671	631		.653	.638	.62	
3C	.747	.736	.716		.697	.673	631		.655	.64	.62	
4B	.752	.737	.70		.702	.674	.60		.662	.641	.61	
4C	.757	.738	.679		.707	.676	.572		.667	.642	.596	
5B	.75	.711	.55		.70	.622	.40		.66	.617	.51	
5C	.755	.722	.55	↓	.705	.643	.40	↓	.665	.624	.51	↓

REHEAT SYS. HEATING EFFICIENCIES, SUMMER

	BASE CASE (I)				RETENTION HEAD (II)			
	BUF	ST.L	MEM	TAM	BUF	ST.L	MEM	TAM
P/U 3A	.316	.47	.53	.65	.40	.60	.65	.73
3B	.33	.36	.40	.57	.41	.45	.51	.68
3C	.345	.37	.43	.58	.44	.47	.55	.69
4B	.44	.47	.55	.65	.56	.61	.67	.73
4C	.48	.54	.59	.65	.63	.66	.69	.73
	NEW BOILER (III)				STACK HEAT RECLAIM (IV			
DU 3A	.565	.71	.74	.79	.42	.61	.67	.77
3B	.57	.60	.65	.75	.43	.47	.53	.70
3C	.59	.62	.68	.76	.46	.49	.57	.71
4B	.69	.71	.75	.79	.58	.62	.69	.77
4C	.71	.74	.77	.79	.63	.68	.72	.77
	VENT DAMPER (V)							
P/U 3A	.52	.61	.65	.70				
3B	.53	.55	.58	.66				
3C	.54	.56	.59	.67				
4B	.60	.62	.66	.70				
4C	.62	.65	.68	.70				

Section E: Cost/Savings Ratios Using Fuel-Adjusted Savings for Retrofits to Forty Building Types in the St. Louis Climate Zone

From these lists of retrofits it can be seen why it was possible to consolidate forty retrofit lists for forty building types into thirteen building types for which the lists were distinct. Some of the consolidation possible included:

a. Retrofit lists for moderate and large size buildings are the same for similar uses, wall types and heating systems.

b. Retrofit lists for buildings with masonry walls and clad walls are similar if heating systems and use types are the same.

These lists were derived from the full set of costs/savings ratios shown in Section J, by applying the fuel factors shown in Section K. The costs per million Btus shown in Section J are simply multiplied by the appropriate fuel factor shown in Section K to get the fuel-adjusted cost per million Btus, as in the following example:

(1) MBW/H_2O/2 (small apartment building with masonry walls and a water-based heating system).

(2) Cost/savings ratio for storm windows (Measure E-3) = 26/MMBtu.

(3) Times fuel cost adjustment factor for St. Louis water systems = .79.

(4) Equals fuel-adjusted savings .79 x $26 = $22/MMBtu.

The fuel cost adjustment factor adjusts for the difference in price between fuel oil at $7.00 per million Btus and electricity at $.06 per kilowatt-hour. The derivation of the fuel cost adjustment factors is presented in Section K.

	TABLE E1 p. 1	Small Frame House			Small Masonry Rowhouse			Moderate Frame Multi-family		
	Retrofit Measure	Air Sys.	Water Sys.	Decentralized	Air Sys.	Water Sys.	Decentralize	Air Sys.	Water Sys.	Decentralize
E-1	ROOF/ATTIC INS.	14	13	10	13	15	17	81	73	59
E-2	WALL INSUL.	6	6	4	114	88	81	6	6	5
E-3	STORM WINDOWS	28	25	18	21	20	16	24	21	17
E-4	DOUBLE GLAZING	116	106	75	91	85	67	98	88	67
E-5	WEATHERSTRIPPIN	14	12	8	9	8	6	35	32	24
E-6	WINDOW INSUL.	61	61	38	53	53	38	46	44	38
E-7	REFLECT. FILMS									
E-8	SHADING DEVICES									
E-9	ROOF SPRAYS							5	3	3
H-1	REPLACE BURNER	46	46		53	53		36	36	
H-2	REPLACE BOILER		53			66			41	
H-3	VENT DAMPER	25	25		38	38		8	6	
H-4	STACK HT. RECL.		36			52			14	
H-5	ELEC. HEAT PUMP			57			80			101
H-6	BOILER TURBUL.								80	
H-7	MODUL. AQUASTAT		10			19			5	
H-8	THERMOSTATS	6	6		9	9	7	10	10	7
H-9	ENTHALPY CONTR.									
H10	REPLACE ROOM AC		16	17		28	28		19	19
H11	REPLACE CENT.AC	139			206			145		
H12	VARY CHW TEMP.							36		
H13	REHEAT-VAV									
H14	REDUCE VENTIL.									
H15	EVAP. COOLING									
H16	WATER-CL. CONDEN							37		
H17	FOG COOLING									
H18	INSULATE DUCTS	42			54			40		
H19	INSULATE PIPES		176			241			178	
H20	2-SPEED FAN MOT	4			5			3		
D-1	SUMMER DHW HTR.								21	
D-2	FLOW CONTROLS	1	1	0.5	1	1	0.5	0.8	0.8	0.5
D-3	INSULATE STORAG	4	4	2	4	4	2	2.4	2.3	0.5
D-4	DHW VENT DAMPER	25	25	11	25		11	2.6	2.6	1
D-5	DHW HEAT PUMP			21			21			21
L-1	INCAN.-FLUOR.							3	4	5
L-2	HYBRID LAMPS	6	9	12	6	9	12	4	6	8
L-3	TASK LIGHTING									
L-4	HI-EFFIC.FLUOR.									

	TABLE E1 p. 2	Multi-family			Multi-family			Commercial		
		Air Sys.	Water Sys.	Decen-tral-ized	Air Sys.	Water Sys.	Decen-tral-ized	Air Sys.	Water Sys.	Decen-tral-ized
E-1	ROOF/ATTIC INS.	55	50	41	59	52	41	86	77	58
E-2	WALL INSUL.	113	102	81	103	93	71	7	6	4
E-3	STORM WINDOWS	22	21	17				25	22	16
E-4	DOUBLE GLAZING	93	85	67	42	38	29	98	88	64
E-5	WEATHERSTRIPPIN	33	30	24	41	38	29	45	40	30
E-6	WINDOW INSUL.	44	42	38	38	36	31	50	47	38
E-7	REFLECT. FILMS							29	28	20
E-8	SHADING DEVICES							18	18	13
E-9	ROOF SPRAYS	4	2	3	7	5	3	5	3	3
H-1	REPLACE BURNER	35	35		33	33		40	40	
H-2	REPLACE BOILER		36			36			49	
H-3	VENT DAMPER	7	5		7	5		9	6	
H-4	STACK HT. RECL.		12			12			14	
H-5	ELEC. HEAT PUMP			100			93			79
H-6	BOILER TURBUL.		90			80			92	
H-7	MODUL. AQUASTAT		5			4			4	
H-8	THERMOSTATS	10	10	7	9	9	7	10	10	6
H-9	ENTHALPY CONTR.	2			2			2		
H10	REPLACE ROOM AC		19	19		18	18		71	71
H11	REPLACE CENT.AC	147			140			672		
H12	VARY CHW TEMP.	24			23			54		
H13	REHEAT-VAV									
H14	REDUCE VENTIL.							0.5		
H15	EVAP. COOLING									
H16	WATER-CL.CONDEN	38			36			142		
H17	FOG COOLING									
H18	INSULATE DUCTS	43			43			24		
H19	INSULATE PIPES		190			176			150	
H20	2-SPEED FAN MOT	3			3			3		
D-1	SUMMER DHW HTR.		21			21				
D-2	FLOW CONTROLS	1	1	0.5	1	1	0.3	3	3	1
D-3	INSULATE STORAG	3	3	1	2	2	0.9	17	17	11
D-4	DHW VENT DAMPER	3	3	1	3	3	1	5	5	2
D-5	DHW HEAT PUMP			21			21			
L-1	INCAN.-FLUOR.	3	4	5	3	4	5	12	16	22
L-2	HYBRID LAMPS	4	7	8	4	6	8	5	7	10
L-3	TASK LIGHTING							15	21	29
L-4	HI-EFFIC.FLUOR.							8	11	15

	TABLE EI· p. 3	Commercial					Commercial			
		Air Sys.	Water Sys.	Decen- tral- ized	Complex Reheat		Air Sys.	Water Sys.	Decen- tral- ized	Complex Reheat
E-1	ROOF/ATTIC INS.	76	51	41	74		57	51	41	74
E-2	WALL INSUL.	115	103	81	135		100	90	71	118
E-3	STORM WINDOWS	17	15	12	19					
E-4	DOUBLE GLAZING	42	39	30	50		41	37	29	48
E-5	WEATHERSTRIPPIN	16	14	11	18		25	24	19	29
E-6	WINDOW INSUL.	36	35	31	35		25	24	19	29
E-7	REFLECT. FILMS	26	25	20	32		26	26	20	39
E-8	SHADING DEVICES	13	12	10	16		13	14	11	18
E-9	ROOF SPRAYS	4	5	3	4		4	4	3	4
H-1	REPLACE BURNER	27	27		6		29	29		6
H-2	REPLACE BOILER		44		8			48		9
H-3	VENT DAMPER	6	4		0.7		6	4		0.8
H-4	STACK HT. RECL.		13		2			14		2.5
H-5	ELEC. HEAT PUMP			122					122	
H-6	BOILER TURBUL.		128		19			133		19
H-7	MODUL. AQUASTAT		3					4		
H-8	THERMOSTATS	9	9	6	11		8	8	6	10
H-9	ENTHALPY CONTR.	2					2			
H10	REPLACE ROOM AC		33	33					35	
H11	REPLACE CENT.AC	318			318		329			
H12	VARY CHW TEMP.	25					26			
H13	REHEAT-VAV				3					3
H14	REDUCE VENTIL.	0.4					0.4			
H15	EVAP. COOLING									
H16	WATER-CL. CONDEN	67			67		69			
H17	FOG COOLING									
H18	INSULATE DUCTS	31			27		28			26
H19	INSULATE PIPES		189					188		
H20	2-SPEED FAN MOT	3					2			
D-1	SUMMER DHW HTR.									
D-2	FLOW CONTROLS	3	3	1	3		3	3	1	3
D-3	INSULATE STORAG	16	16	11	19		16	16	11	19
D-4	DHW VENT DAMPER	5	5	2	5		5	5	2	5
D-5	DHW HEAT PUMP									
L-1	INCAN.-FLUOR.	11	18	22	18		11	18	22	18
L-2	HYBRID LAMPS	5	8	10	8		5	8	10	8
L-3	TASK LIGHTING	15	24	29	24		15	24	29	24
L-4	HI-EFFIC. FLUOR.	8	13	15	13		8	13	15	13

	TABLE EI. p. 4	Commercial					Commercial			
		Air Sys.	Water Sys.	Decen-tral-ized	Complex Reheat		Air Sys.	Water Sys.	Decen-tral-ized	Complex Reheat
E-1	ROOF/ATTIC INS.	57	51	41	74		57	52	41	73
E-2	WALL INSUL.	115	103	81	130		101	91	71	118
E-3	STORM WINDOWS									
E-4	DOUBLE GLAZING	31	28	22	36		41	37	29	73
E-5	WEATHERSTRIPPIN	19	17	14	22		38	35	29	44
E-6	WINDOW INSUL.	36	35	31	35		45	45	31	36
E-7	REFLECT. FILMS	23	22	20	28		24	23	34	28
E-8	SHADING DEVICES	11	11	10	14		24	13	13	17
E-9	ROOF SPRAYS	4	3	3	4		4	3	3	4
H-1	REPLACE BURNER	15	15		2		18	18		2
H-2	REPLACE BOILER		47		7			38		5
H-3	VENT DAMPER	4	2		0.3		15	15		3
H-4	STACK HT. RECL.	13	13		2		15	15		3
H-5	ELEC. HEAT PUMP			150						
H-6	BOILER TURBUL.		128		13			120		10
H-7	MODUL.AQUASTAT		1					2		
H-8	THERMOSTATS	8	8	6	10		8	8	6	10
H-9	ENTHALPY CONTR.	0.4					0.5			
H10	REPLACE ROOM AC		42	42				44	44	
H11	REPLACE CENT.AC	332			332		349			349
H12	VARY CHW TEMP.	6					6			
H13	REHEAT-VAV				3					3
H14	REDUCE VENTIL.	0.3					0.5			
H15	EVAP. COOLING									
H16	WATER-CL.CONDEN	61			61		28			86
H17	FOG COOLING									
H18	INSULATE DUCTS	25			31		19			23
H19	INSULATE PIPES		141					140		
H20	2-SPEED FAN MOT	2					3			
D-1	SUMMER DHW HTR.									
D-2	FLOW CONTROLS	0.5	0.5	0.3	0.3		1	0.5	0.5	0.5
D-3	INSULATE STORAG	16	16	11	27		13	16	11	20
D-4	DHW VENT DAMPER	1	1	0.5	1		1	1	0.5	1
D-5	DHW HEAT PUMP									
L-1	INCAN.-FLUOR.	11	18	22	18		11	18	22	18
L-2	HYBRID LAMPS	4	6	7	6		4	6	7	6
L-3	TASK LIGHTING	26	59	35	52		26	58	35	52
L-4	HI-EFFIC.FLUOR.	8	13	15	13		8	12	15	13

TABLE E1. p. 5		Large Masonry Multi-family			Large Cladwall Multi-family					
		Air Sys.	Water Sys.	Decentralized	Air Sys.	Water Sys.	Decentralized			
E-1	ROOF/ATTIC INS.	52	47	41	54	49	41			
E-2	WALL INSUL.	105	96	81	95	86	71			
E-3	STORM WINDOWS									
E-4	DOUBLE GLAZING	37	34		39	35	29			
E-5	WEATHERSTRIPPIN	49	45	39	51	47	39			
E-6	WINDOW INSUL.	40	40	31	35	33	31			
E-7	REFLECT. FILMS									
E-8	SHADING DEVICES									
E-9	ROOF SPRAYS	4	3	3	4	5	3			
H-1	REPLACE BURNER	7	7		7	7				
H-2	REPLACE BOILER		12			13				
H-3	VENT DAMPER	4	4		2	1				
H-4	STACK HT. RECL.		7			4				
H-5	ELEC. HEAT PUMP			50			49			
H-6	BOILER TURBUL.		43			45				
H-7	MODUL.AQUASTAT		1			1				
H-8	THERMOSTATS	7	7	6	7	7	6			
H-9	ENTHALPY CONTR.	0.5		-	0.5					
H10	REPLACE ROOM AC		23	26		25	25			
H11	REPLACE CENT.AC	137			134					
H12	VARY CHW TEMP.	7			7					
H13	REHEAT-VAV									
H14	REDUCE VENTIL.									
H15	EVAP. COOLING									
H16	WATER-CL.CONDEN	27			27					
H17	FOG COOLING									
H18	INSULATE DUCTS	42			41					
H19	INSULATE PIPES		174							
H20	2-SPEED FAN MOT	1			1					
D-1	SUMMER DHW HTR.		21			21				
D-2	FLOW CONTROLS	1	1	0.5	1	1	0.5			
D-3	INSULATE STORAG	3	3	1	3	3	1			
D-4	DHW VENT DAMPER	0.5	0.5	0.5	0.7	1	0.3			
D-5	DHW HEAT PUMP			17			17			
L-1	INCAN.-FLUOR.	4	6	7	4	6	7			
L-2	HYBRID LAMPS	3	6	6	3	6	6			
L-3	TASK LIGHTING									
L-4	HI-EFFIC.FLUOR.									

Section F: Cost/Savings Ratios (using fuel-adjusted savings) for 4 Building Types in Four Climate Zones

These lists of retrofits illustrate the variations in retrofit lists for the same building type as the climate varies. The actual climate values are described in Section D: Detailed Parameters of the Building Models. The building types are the same as the four for which retrofit lists were published in Chapter 3 of the full report. As can be seen, the lists do not vary greatly from city to city except for Tampa.

The cost/savings ratio is expressed as full capital cost (unamortized) per million Btu saved (annually). For translations to other typical cost benefit expressions see Box B on p. 46 of the full report. The cost/savings ratio has been multiplied by a fuel cost adjustment factor as explained in Section E.

TABLE F1 p. 1	Retrofit Measure	Small Frame House with Central Water System and Window Air Conditioners				Small Masonry Rowhouse with Central Air Heating And Cooling			
		Buf.	St. L.	Mem.	Tampa	Buf.	St. L.	Mem.	Tampa
E-1	ROOF/ATTIC INS.	13	13	16	14	21	13	26	31
E-2	WALL INSUL.	6	6	7	7	106	114	127	155
E-3	STORM WINDOWS	22	25	30	28	19	21	25	32
E-4	DOUBLE GLAZING	93	106	123	117	76	91	104	132
E-5	WEATHERSTRIPPIN	8	12	14	149	6	9	10	14
E-6	WINDOW INSUL.	43	62	83	136	39	53	67	304
E-7	REFLECT. FILMS								
E-8	SHADING DEVICES								
E-9	ROOF SPRAYS								
H-1	REPLACE BURNER	34	46	52	127	38	53	72	274
H-2	REPLACE BOILER	37	53	65	109				
H-3	VENT DAMPER	9	25	18	26	13	38	22	61
H-4	STACK HT. RECL.	25	36	52	141				
H-5	ELEC. HEAT PUMP								
H-6	BOILER TURBUL.								
H-7	MODUL.AQUASTAT	6	10	13	49				
H-8	THERMOSTATS	4	6	6	16	7	9	9	30
H-9	ENTHALPY CONTR.								
H10	REPLACE ROOM AC	35	16	15	9				
H11	REPLACE CENT.AC					425	206	184	133
H12	VARY CHW TEMP.								
H13	REHEAT-VAV								
H14	REDUCE VENTIL.								
H15	EVAP. COOLING								
H16	WATER-CL.CONDEN								
H17	FOG COOLING								
H18	INSULATE DUCTS					64	54	47	23
H19	INSULATE PIPES	125	176	213	266				
H20	2-SPEED FAN MOT					3	5	5	9
D-1	SUMMER DHW HTR.								
D-2	FLOW CONTROLS	1	1	1	1	1	1	1	1
D-3	INSULATE STORAG	5	4	4	4	4	4	4	4
D-4	DHW VENT DAMPER	27	25	27	27	27	25	27	27
D-5	DHW HEAT PUMP								
L-1	INCAN.-FLUOR.								
L-2	HYBRID LAMPS	11	9	8	10	6	6	6	8
L-3	TASK LIGHTING								
L-4	HI-EFFIC.FLUOR.								

	TABLE F1 p. 2	Large Masonry Multi-Family Building With Decentralized Heating and Cooling					Large Cladwall Commercial Building With Complex Reheat System			
	MEASURE	Buf.	St. L.	Mem.	Tampa		Buf.	St. L.	Mem.	Tampa
E-1	ROOF/ATTIC INS.	35	41	50	70		67	73	86	104
E-2	WALL INSUL.	70	81	98	137		108	118	138	179
E-3	STORM WINDOWS									
E-4	DOUBLE GLAZING	25	29	35	49		43	48	57	73
E-5	WEATHERSTRIPPIN	25	39	50	76		28	44	52	117
E-6	WINDOW INSUL.	21	31	43	306		33	36	52	114
E-7	REFLECT. FILMS						26	28	35	49
E-8	SHADING DEVICES						16	17	19	27
E-9	ROOF SPRAYS	4	3	2	2		5	4	3	2
H-1	REPLACE BURNER						2	2	2	3
H-2	REPLACE BOILER						5	5	4	5
H-3	VENT DAMPER						3	3	3	3
H-4	STACK HT. RECL.						2	2	2	1
H-5	ELEC. HEAT PUMP	46	50	37						
H-6	BOILER TURBUL.						10	10	10	8
H-7	MODUL.AQUASTAT									
H-8	THERMOSTATS	4	6	7	33		7	10	10	8
H-9	ENTHALPY CONTR.									
H10	REPLACE ROOM AC	52	26	23	15					
H11	REPLACE CENT.AC						640	349	308	206
H12	VARY CHW TEMP.									
H13	REHEAT-VAV						3	3	3	3
H14	REDUCE VENTIL.									
H15	EVAP. COOLING									
H16	WATER-CL.CONDEN						119	86	59	41
H17	FOG COOLING									
H18	INSULATE DUCTS						26	23	38	63
H19	INSULATE PIPES									
H20	2-SPEED FAN MOT									
D-1	SUMMER DHW HTR.									
D-2	FLOW CONTROLS	0.5	0.5	0.5	0.5		0.5	0.5	0.5	0.5
D-3	INSULATE STORAG	1	1	1	1		15	20	20	40
D-4	DHW VENT DAMPER	0.5	0.5	0.5	0.5		1	1	1	1
D-5	DHW HEAT PUMP	17	17	17	17					
L-1	INCAN.-FLUOR.	11	7	7	4		22	18	18	14
L-2	HYBRID LAMPS	10	6	6	4		8	6	6	5
L-3	TASK LIGHTING						108	52	50	27
L-4	HI-EFFIC.FLUOR.						16	13	13	10

Section G: Cost/Savings Ratios for Solar Retrofit to Three Building Types in Four Climate Zones

These tables show the costs per million Btu as calculated for seven solar retrofits (including passive solar) to three building types in four climate zones. How these estimates were made is briefly described at the end of Section L.

Total Retrofit Cost / ft^2	SINGLE FAMILY				SMALL MULTIFAMILY				LARGE MULTIFAMILY			
	B	SL	M	T	B	SL	M	T	B	SL	M	T
R-1. Solar DHW	.75	.49	.49	.49	.97	.81	.71	.52	6.48	4.86	4.54	3.24
R-2. Solar combined	7.30	6.10	4.86	2.43	3.24	2.43	.97	--	2.18	1.22	.73	--
R-3. Sunspace	3.88	3.88	3.88	3.88	--	--	--	--	--	--	--	--
R-4. Glaze masonry wall	1.40	1.40	1.40	1.40	.47	.47	.47	.47	.35	.35	.35	.35
R-5. Add wall panel	1.00	1.00	1.00	1.00	.33	.33	.33	.33	.30	.30	.30	.30
R-6. Add glazing with night insulation	.25	.25	.25	.25	.17	.17	.17	.17	.15	.15	.15	.15
R-7. Add glazing with storage	.70				.47	.47	.47	.47	.35	.35	.35	.35

Annual Energy Savings Thousand Btu / ft^2	SINGLE FAMILY				SMALL MULTIFAMILY				LARGE MULTIFAMILY			
	B	SL	M	T	B	SL	M	T	B	SL	M	T
R-1. Solar DHW	8.5	6.4	6.8	7.7	12.9	11.3	10.6	9.8	11.5	9.4	9.3	8.3
R-2. Solar combined	51.7	46.7	35.8	20	28.3	24.2	12.8	--	20.3	14.8	9.7	--
R-3. Sunspace	--	--	--	13.3	--	--	--	--	--	--	--	--
R-4. Glass masonry wall	10.8	21.7	19.2	16.7	4.8	8.2	7.8	--	1.3	4.8	3.7	--
R-5. Add wall panel	10	8.3	6.7	5	3.3	2.8	2.2	--	3	2.5	2	--
R-6. Add glazing with night insulation	5.8	15	15	10	2.8	3.5	5.2	--	3.8	5.2	3.8	--
R-7. Add glazing with storage	10.8	17.5	16.7	21.7	8.8	6.3	5.8	--	7	4.8	3.8	--

Cost per Annual Million Btu Saved	SINGLE FAMILY				SMALL MULTIFAMILY				LARGE MULTIFAMILY			
	B	SL	M	T	B	SL	M	T	B	SL	M	T
R-1. Solar DHW	86	74	72	64	75	72	67	53	85	77	73	58
R-2. Solar Combined	142	131	137	122	114	100	76	--	108	82	26	--
R-3. Sunspace	--	--	--	422	--	--	--	--	--	--	--	--
R-4. Glaze masonry wall	129	65	73	84	95	57	59	--	274	72	94	--
R-5. Add wall panel	100	120	150	200	100	120	150	--	100	120	150	--
R-6. Add glazing with night insulation	43	17	17	25	57	47	32	--	39	29	39	--
R-7. Add glazing with storage	65	40	42	32	53	73	82	--	50	72	91	--

KEY: B - Buffalo
SL - St. Louis
M - Memphis
T - Tampa

Section H: Costs of Retrofits

These tables show the estimated costs of each retrofit to each building type. The abbreviations -- P/U IA etc. -- for building type are explained in Section D. The sources for the cost estimates are given in the section on sources in Section L.

COST MATRIX-1

	ENVELOPE							
	ROOF/ATTIC INSULATION	WALL INSULATION	STORM WINDOWS	DOUBLE GLAZING	WINDOW/ DOOR WS	WINDOW INSULATION	REFLECTIVE FILMS	SHADING DEVICES
PU 1A	565	646	990	4092	110	910	NA	NA
1B	690	4664	450	1860	60	420	"	"
2A	12,000	2800	4230	17,480	1790	3940	"	"
2B	"	41,740	"	17,480	1790	3940	"	"
2C	"	41,740	N.A.	6750	1790	3940	"	"
3A	"	2555	6160	24,630	2700	6300	4050	4990
3B	"	38,160	"	15,910	2700	6300	4050	4990
3C	"	38,160	N.A.	10,800	1050	6300	4050	4230
4B	30,000	133,560	NA	64,800	15,900	37,800	24,300	28,380
4C	"	133,560	NA	64,800	6,000	37,800	24,300	25,380
5B	"	216,240	NA	43,200	5520	25,200	NA	NA
5C	"	216,240	NA	43,200	5520	25,200	"	"

COST MATRIX - 2

	ENVELOPE	H V A C						
	ROOF SPRAYS	FOG COOLING	REPLACE BOILER		VENT DAMPER		STACK ECONOMIZER	
PU 1A	NA		BUF 1728 ST.L. 1632	MEM 1392 TAM. 1056	BUF 225 ST.L 225	MEM 225 TAM 225	BUF 875 ST.L 875	MEM. 875 TAM. 750
1B	NA		BUF 1392 ST.L 1320	MEM. 1152 TAM. 960	225 225	225 225	850 800	750 700
2A	1500		BUF 4620 ST.L 4500	MEM. 3840 TAM. 2300	1250 1250	800 450	1400 1200	1100 950
2B	1500		BUF 8450 ST.L 4560	MEM 4080 TAM 2496	1250 1250	800 450	1800 1200	1100 950
2C	1500		BUF 8470 ST.L 4680	MEM 4320 TAM 2500	1250 1250	800 450	1800 1250	1200 950
3A	1500		BUF 8640 ST.L 5460	MEM 4500 TAM 2760	1250 1250	800 450	1820 1250	1200 950
3B	1500		BUF 9540 ST.L 8470	MEM 7380 TAM 4440	1250 1250	800 450	1860 1820	1800 1200
3C	1500		BUF 8470 ST.L 8280	MEM 6780 TAM 4140	1250 1250	800 450	1820 1820	1700 1200
4B	3750		33280 26650	16200 9840	2000 2000	1250 800	6600 5500	4800 1870
4C	3750		21580 16200	13200 8400	2000 2000	1250 800	5500 4900	4300 1820
5B	3750		13500 12240	10440 6720	1600 1600	1250 800	4400 3200	1880 1550
5C	3750		13920 12960	10560 6840	1600 1600	1250 800	4400 3300	1900 1600

COST MATRIX - 3

	H V A C							
	REPLACE ELECTRIC RESISTANCE W/HEAT PUMP		BOILER TURBULATORS		MODULATING AQUASTAT	SETBACK THERMOSTATS	ENTHALPY CONTROL	REPLACE ROOM A/C
PU. 1A	BUF 6130 ST.L 5520	MEN. 4860 TAM. 3065	NA	NA	250	135	NA	890
1B	4860 3680	3240 1620	NA	NA	250	135	NA	890
2A	27,600 24,300	18,400 9375	BUF 1840 ST.L 1620	MEN. 1340 TAM. 775	400	1080	2060	5930
2B	45,980 24,300	18,400 9375	3700 1840	1460 780	400	1080	2060	5930
2C	45,980 27,600	22,000 9600	3750 1900	1500 840	400	1080	2060	5930
3A	53,600 28,000	22,000 9600	4140 2180	1570 1010	400	1080	2400	11855
3B	62,300 53,600	42,880 22,400	4780 4140	3360 1790	400	1080	2400	11855
3C	53,600 48,240	38,200 22,000	4140 3920	2800 1620	400	1080	2400	11855
4B	189,600 155,440	123,280 64,990	15,900 12,320	9180 4930	535	4320	3000	75870
4C	139,360 119,260	94,470 36,850	10,800 8850	7730 4030	535	4320	3000	75870
5B	108,000 108,000	78,000 54,000	7840 6720	4930 2800	535	4320	2800	39520
5C	108,000 108,000	78,000 54,000	8180 7170	4980 2900	535	4320	2800	39520

COST MATRIX - 4

	H V A C						
	REPLACE CENTRAL A/C	VARY CHW TEMP. w/LOAD	CONVERT REHEAT → VAV	REDUCE VENTILATION VOLUME	EVAPORATIVE COOLING	WATER-COOLED CONDENSER	REPLACE	BURNER
PU 1A	1800	NA	NA	NA		1200	BUF. 950 ST.L. 880	MEM. 750 TAM. 570
1B	1600	NA	NA	NA		1200	750 715	620 520
2A	9600	2230	NA	190		3630	2800 2650	1900 1200
2B	9600	2230	NA	190		3630	3350 2900	2300 1250
2C	9600	2230	NA	190		3600	3400 2900	2300 1250
3A	23,500	2600	3600	265		7180	3500 2900	2350 1250
3B	23,500	2600	3600	265		7180	3600 3350	3200 2350
3C	23,500	2600	3600	265		7180	3500 3300	3150 2250
4B	180,000	3200	10830	910		32,300	6800 5600	5200 3600
4C	180,000	3200	10830	910		32,300	5200 5000	4450 3320
5B	44,000	3200	NA	760		12,750	4600 4300	3650 3150
5C	44,000	3200	NA	760		12,750	4700 4350	3700 3200

COST MATRIX - 5

	H V.A C					D H W		
	INSULATE DUCTS		INSULATE PIPES		TWO-SPEED FAN MOTORS	SUMMER DHW BOILER	FLOW CONTROLS	INSULATE STORAGE
PU 1A	BUF 1440 ST.L 1230	MEM 980 TAM 640	500		110	NA	19	30
1B	940 810	640 430	500		80	NA	19	30
2A	5570 4710	3740 3150	2320		480	1230	173	450
2B	5570 4710	3740 3150	2320		480	1230	173	450
2C	5570 4710	3740 3150	2320		480	1230	173	450
3A	11600 7890	7845 7845	2320		585	NA	8	165
3B	13310 11500	9585 9585	2320		585	NA	8	165
3C	11590 10260	9296 9160	2320		585	NA	8	165
4B	47,010		7180		1185	NA	32	590
4C	44,600		7180		1185	NA	32	590
5B	25,650		7180		975	10,700	1550	3350
5C	25,900		7180		975	10,700	1550	3350

COST MATRIX-6

	DHW			LIGHTING			
	VENT DAMPER	AIR→WATER HEAT PUMP		REPLACE INCANDESCENT W/FLUORESCENT	FLUOR. HYBRID LAMPS	TASK LIGHTING	HIGH-EFFICIENCY FLUORESCENTS
PU 1A	150	980		NA	100	NA	NA
1B	150	980		NA	100	NA	NA
2A	200	2530		1415	1350	NA	NA
2B	200	2530		1415	1350	NA	NA
2C	200	2530		1415	1350	NA	NA
3A	150	1370		38,660	17,180	10,240	2120
3B	150	1370		38,660	17,180	10,240	2120
3C	150	1370		38,660	17,180	10,240	2120
4B	200	2800		232,540	76,390	68,000	12,750
4C	200	2800		232,540	76,390	68,000	12,750
5B	225	13960		14,900	9310	NA	NA
5C	225	13960		14,900	9310	NA	NA

Section I: Energy Savings for Each Retrofit for Each Building Type (without fuel-adjustment)

For this section also, a key to the abbreviations used can be found in Section D, and the sources of savings and algorithms in the reference sources in Section L.

A few of the savings estimates shown here, e.g. lighting savings in buildings with water (H_2O) central heating systems, were later found to be in error. These are circled and crossed out in the tables.

E-1:ROOF/ATTIC INSULATION MMBTU SAVINGS

ROOF INS	BUFFALO WATER	BUFFALO DECENT.	ST.LOUIS WATER	ST.LOUIS DECENT.	MEMPHIS WATER	MEMPHIS DECENT.	TAMPA WATER	TAMPA DECENT
PU 1A	40.57	27.60	33.21	23.60	27.16	19.60	17.56	14.00
PU 1B	43.84	27.60	37.03	23.60	31.77	19.60	17.56	14.00
PU 2A	154.67	97.40	129.26	83.40	101.02	69.20	63.21	49.50
PU 2B	250.02	138.70	189.17	118.90	147.94	98.60	88.28	70.60
PU 2C	245.28	138.70	180.52	118.90	162.40	98.60	88.28	70.60
PU 3A	165.67	98.10	122.92	84.10	105.22	69.70	63.68	49.90
PU 3B	225.25	137.90	185.17	118.20	153.89	98.00	87.81	70.20
PU 3C	223.70	137.90	185.17	118.20	153.89	98.00	87.81	70.20
PU 4B	546.11	344.90	462.93	295.50	397.16	245.10	219.52	175.50
PU 4C	539.78	344.90	459.32	295.50	410.75	245.10	219.52	175.50
PU 5B	549.79	344.90	503.28	295.50	556.52	245.10	219.52	175.50
PU 5C	542.47	344.90	486.15	295.50	556.52	245.10	219.52	175.50

ROOF INS.	BUF COMP	BUF AIR	ST.L COMP	ST.L AIR	MEM COMP	MEM AIR	TAM COMP	TAM AIR
	NA	39.08	NA	31.51	NA	25.18	ERROR	NA
	NA	43.40	NA	35.38	NA	29.74	ERROR	NA
	NA	152.78	NA	122.22	NA	92.70	ERROR	NA
	NA	247.01	NA	178.57	NA	135.25	ERROR	NA
	NA	241.94	NA	169.93	NA	150.00	ERROR	NA
	121.50	161.76	94.83	115.38	73.66	95.93	38.28	48.53
	167.51	219.71	130.95	174.23	101.85	141.03	52.72	66.80
	167.51	219.71	130.95	174.23	101.85	141.03	52.72	66.80
	418.78	539.92	327.38	435.59	254.63	365.04	131.79	167.00
	418.78	530.89	327.38	431.94	254.63	378.44	131.79	167.00
	ERROR	539.92	ERROR	475.78	ERROR	524.14	ERROR	167.00
	ERROR	530.89	ERROR	458.84	ERROR	524.14	ERROR	167.00

E-2: INSULATE WALLS

INSULAT. MMBTU	BUFFALO AIR	BUFFALO WATER	ST.LOUIS AIR	ST.LOUIS WATER	MEMPHIS AIR	MEMPHIS WATER	TAMPA AIR	TAMPA WATER
PU 1A	128.41	128.41	100.89	106.60	80.71	86.92	45.56	55.94
PU 1B	41.64	42.40	34.04	35.60	28.61	30.48	13.80	16.84
PU 2A	666.67	682.93	538.46	571.43	400.00	444.44	213.74	277.23
PU 2B	422.47	428.98	304.67	323.57	231.89	252.97	116.27	150.69
PU 2C	476.48	483.66	333.92	353.73	293.94	318.63	133.78	173.20
PU 3A	638.75	655.13	456.25	491.35	381.34	418.85	193.56	252.97
PU 3B	346.91	350.09	274.53	291.30	221.86	241.52	105.12	137.76
PU 3C	397.09	403.81	315.37	334.74	254.40	278.54	120.76	158.34
PU 4B	1192.50	1214.18	960.86	1019.54	804.58	872.94	367.93	482.17
PU 4C	1342.31	1367.04	1094.75	1161.39	954.00	1035.35	422.66	554.19
PU 5B	1930.71	1965.82	1689.38	1787.11	1864.14	1983.85	595.70	780.65
PU 5C	2173.27	2213.31	1880.35	1983.85	2140.99	2278.61	684.30	897.26

MMBTU	BUFFALO DECENT.	BUFFALO COMPLEX	ST.LOUIS DECENT.	ST.LOUIS COMPLEX	MEMPHIS DECENT.	MEMPHIS COMPLEX	TAMPA DECENT.	TAMPA COMPLEX
PU 1A	102.54	137.45	88.49	105.90	73.41	82.82	52.52	43.07
PU 1B	27.27	36.16	23.32	28.10	19.27	21.90	13.80	11.32
PU 2A	444.44	595.74	383.56	459.02	318.18	358.97	227.64	175.00
PU 2B	242.67	323.57	208.70	251.45	172.48	192.35	1231.27	94.22
PU 2C	278.27	369.38	238.51	283.95	198.76	220.85	141.97	108.13
PU 3A	98.27	98.27	98.27	98.27	98.27	98.27	98.27	98.27
PU 3B	221.86	293.54	190.80	225.80	157.69	174.25	112.90	84.99
PU 3C	254.40	337.70	218.06	259.59	181.71	200.84	130.24	97.60
PU 4B	776.51	1027.38	667.80	790.30	551.90	609.86	395.15	297.46
PU 4C	890.40	112.90	763.20	908.57	609.86	702.95	455.84	341.59
PU 5B	1257.21	129.72	1081.20	1279.53	893.55	987.40	639.76	481.60
PU 5C	1441.60	112.86	1235.66	1471.02	1029.71	1138.11	738.02	553.04

E-3; STORM WINDOWS

STORM WINDOWS MMBTU	BUFFALO AIR	BUFFALO WATER	ST.LOUIS AIR	ST.LOUIS WATER	MEMPHIS AIR	MEMPHIS WATER	TAMPA AIR	TAMPA WATER
PU 1A	40.24	40.74	29.03	30.56	22.92	24.63	12.71	15.54
PU 1B	22.84	23.08	16.67	17.37	13.85	14.71	6.42	7.84
PU 2A	202.39	205.34	146.88	155.51	110.73	120.51	56.25	72.93
PU 2B	233.70	237.64	154.38	163.32	115.89	125.89	56.25	72.93
PU 2C	NA	NA	NA	NA	NA	NA	NA	NA
PU 3A	315.90	320.83	206.71	220.00	170.17	186.67	83.92	110.00
PU 3B	421.92	427.78	308.00	325.93	247.39	267.83	113.24	148.43
PU 3C	NA	NA	NA	NA	NA	NA	NA	NA
PU 4B	NA	NA	NA	NA	NA	NA	NA	NA
PU 4C	NA	NA	NA	NA	NA	NA	NA	NA
PU 5B	NA	NA	NA	NA	NA	NA	NA	NA
PU 5C	NA	NA	NA	NA	NA	NA	NA	NA

MMBTU	BUFFALO DECENT.	BUFFALO COMPLEX	ST.LOUIS DECENT	ST.LOUIS COMPLEX	MEMPHIS DECENT.	MEMPHIS COMPLEX	TAMPA DECENT.	TAMPA COMPLEX
PU 1A	28.37	NA	22.15	NA	30.46	NA	12.69	NA
PU 1B	14.80	NA	11.31	NA	16.92	NA	6.16	NA
PU 2A	133.86	NA	104.44	NA	154.38	NA	59.49	NA
PU 2B	133.86	NA	104.44	NA	142.91	NA	59.49	NA
PU 2C	NA	NA	NA	NA	NA	NA	NA	NA
PU 3A	199.35	264.38	156.74	187.23	128.33	142.92	89.80	67.62
PU 3B	270.18	360.23	212.41	254.55	173.52	193.71	121.02	91.26
PU 3C	NA	NA	NA	NA	NA	NA	NA	NA
PU 4B	NA	NA	NA	NA	NA	NA	NA	NA
PU 4C	NA	NA	NA	NA	NA	NA	NA	NA
PU 5B	NA	NA	NA	NA	NA	NA	NA	NA
PU 5C	NA	NA	NA	NA	NA	NA	NA	NA

E-4: REPLACEMENT DOUBLE GLAZING MMBTU SAVINGS

DOUBLE GLAZING	BUF AIR	BUF WATER	ST.L AIR	ST.L WATER	MEM AIR	MEM WATER	TAM AIR	TAM WATER
PU 1A	40.60	40.80	29.20	30.50	23.10	24.60	12.80	15.60
PU 1B	23.10	23.10	16.90	17.40	14.00	14.70	6.50	7.90
PU 2A	204.60	205.60	148.50	155.70	111.60	120.70	56.70	72.90
PU 2B	236.90	237.50	156.10	163.30	116.90	125.90	56.70	72.90
PU 2C	189.00	191.90	132.40	140.70	116.90	126.50	53.00	68.80
PU 3A	319.90	321.70	208.40	220.30	172.00	186.60	84.50	110.00
PU 3B	427.30	429.30	311.60	326.90	94.60	268.30	96.60	1485.00
PU 3C	275.60	280.50	218.50	232.20	176.80	192.90	83.80	110.10
PU 4B	2368.00	2374.00	1764.00	1854.00	1464.00	1574.00	650.20	846.10
PU 4C	1598.00	1627.00	1300.00	1382.00	1139.00	1236.00	503.00	660.60
PU 5B	1084.00	1103.00	954.80	1010.00	1052.00	1117.00	335.40	440.40
PU 5C	1065.00	1085.00	920.40	975.00	1052.00	1117.00	335.40	440.40
	DECENT	COMPLEX	DECENT	COMPLEX	DECENT	COMPLEX	DECENT	COMPLEX
PU 1A	28.40	37.90	22.20	26.90	18.20	20.70	12.70	10.40
PU 1B	15.00	19.80	11.30	13.80	9.20	10.60	6.40	5.30
PU 2A	134.00	178.00	105.00	125.00	85.20	95.60	59.50	45.40
PU 2B	134.00	178.00	105.00	125.00	85.20	95.60	59.50	45.40
PU 2C	110.80	147.00	94.90	113.00	78.70	87.40	56.40	42.90
PU 3A	199.30	265.00	157.00	187.00	128.00	143.00	89.80	67.60
PU 3B	270.70	360.00	213.00	254.00	174.00	194.00	121.00	91.20
PU 3C	177.20	235.00	152.00	180.00	126.00	139.00	90.20	67.70
PU 4B	1522.00	2022.00	1206.00	1442.00	907.00	1101.00	691.00	519.00
PU 4C	1063.00	1409.00	911.00	1082.00	756.00	835.00	541.00	406.00
PU 5B	708.80	939.00	607.00	722.00	504.00	557.00	361.00	271.00
PU 5C	708.80	939.00	607.00	722.00	504.00	557.00	361.00	271.00

E-5: WINDOW AND DOOR WEATHERSTRIPPING MMBTU SAVINGS

WEATHER STRIPPING	BUFFALO AIR	BUFFALO WATER	ST.LOUIS AIR	ST.LOUIS WATER	MEMPHIS AIR	MEMPHIS WATER	TAMPA AIR	TAMPA WATER
PU 1A	12.7	12.8	7.1	7.4	5.4	5.7	2.7	3.3
PU 1B	10	10.1	5.9	6.1	4.7	5	2	2.4
PU 2A	71.5	72.5	42.9	45.2	31.3	33.7	14.6	18.8
PU 2B	82.8	83.8	45.2	47.4	32.8	35.3	14.6	18.8
PU 2C	60	60.9	35.5	37.3	30.3	32.4	12.2	15.8
PU 3A	95.7	97	50	52.9	40	43.2	17.8	23.3
PU 3B	229.2	232.6	140.7	148	110	118	46	59.9
PU 3C	60	60	35.4	36.8	28.5	30.7	9.7	12.3
PU 4B	1111	1127	687	722	554	594	223	291
PU 4C	226.5	229.9	131	135	117	125	32.3	39.9
PU 5B	139	141	92.8	97.2	99.9	105	27.9	36.4
PU 5C	136.6	138.7	89.4	93.8	99.9	105	27.9	36.4

	BUF DEC	BUF COMP	ST.L DEC	ST.L COMP	MEM DEC	MEM COMP	TAM DEC	TAM COMP
PU 1A	8.9	11.9	5.3	6.6	4.1	4.8	2.2	2.2
PU 1B	6.4	8.6	3.9	4.8	3	3.6	2	1.6
PU 2A	47.1	63	29.9	36.5	23.4	26.9	15.2	11.7
PU 2B	47.1	63	29.9	36.5	23.4	26.9	15.2	11.7
PU 2C	35	46.6	24.7	30.1	19.5	22.4	12.8	9.8
PU 3A	59.8	79.9	37.1	45.3	29	33.3	18.8	14.2
PU 3B	146	195	94.9	115.5	74.5	85.4	48.4	36.7
PU 3C	38.2	51.1	23	28.9	19.4	22.2	9.3	7.3
PU 4B	720	962	467	564	363	416	235	178
PU 4C	149	199	84	108	73.3	84.2	28.7	23.3
PU 5B	90.1	120	57.2	69.6	45.1	51.6	29.4	22.3
PU 5C	90.1	120	57.2	69.6	45.1	51.6	29.4	22.3

E-7: REFLECTIVE FILMS

REFLECT.FILMS MMBTU	BUF AIR	BUF WATER	ST.L AIR	ST.L WATER	MEM AIR	MEM WATER	TAM AIR	TAM WATER
PU 3A	45.79	53.82	26.51	39.96	32.65	48.14	42.80	63.99
PU 3B	47.74	55.77	24.56	38.00	29.42	44.91	42.80	63.99
PU 3C	45.28	55.35	21.71	38.58	27.95	47.39	37.40	63.99
PU 4B	293.70	354.15	125.16	226.48	163.14	279.87	223.74	383.01
PU 4C	290.45	350.90	130.43	231.75	151.10	267.82	223.74	383.01

MMBTU	BUF DECENT	BUF COMP	ST.L DECENT	ST.L COMP	MEM DECENT	MEM COMP	TAM DECENT	TAM COMP
PU 3A	46.77	44.44	44.55	27.66	53.09	34.31	77.56	53.76
PU 3B	46.77	44.44	44.55	27.66	53.09	34.31	77.56	53.76
PU 3C	46.77	42.40	44.55	24.23	53.09	30.36	77.56	48.35
PU 4B	280.14	253.72	267.57	145.59	319.00	182.59	464.40	289.48
PU 4C	280.14	253.72	267.57	145.59	319.00	182.59	464.40	289.48

E-6: WINDOW INSULATION MMBTU SAVINGS

WINDOW INSUL.	BUF A/W/COM	BUF OFCENT	ST.L A/W/COM	ST.L DECENT	MEM A/W/COM	MEM DECENT	TAM A/W/COM	TAM DECENT
PU 1A	21.34371	14.46629	14.70945	9.724583	10.95502	6.938180	2.994177	.9980591
PU 1B	10.73049	6.676750	7.760158	4.488269	6.265247	3.202237	1.381928	.4606427
PU 2A	98.83347	62.59453	70.12921	42.07752	50.03496	30.02097	12.95557	4.318525
PU 2B	114.9695	62.59453	74.25445	42.07752	52.97819	30.02097	12.95557	4.318525
PU 2C	137.7913	76.55074	85.76536	51.45922	73.42902	36.71451	15.84418	5.281392
PU 3A	166.9188	100.1513	104.4683	67.32404	83.13500	48.03356	20.72892	6.909640
PU 3B	200.4237	122.4812	142.5024	82.33474	110.1435	58.74322	25.35068	8.450228
PU 3C	200.4237	122.4812	142.5024	82.33474	110.1435	58.74322	25.35068	8.450228
PU 4B	1181.069	734.8871	855.0147	494.0085	689.5943	352.4593	152.1041	50.70137
PU 4C	1160.348	734.8871	846.8717	494.0085	720.9395	352.4593	152.1041	50.70137
PU 5B	787.3790	489.9247	630.6491	329.3390	704.9186	234.9729	101.4027	33.80091
PU 5C	773.5653	489.9247	604.9083	329.3390	704.9186	234.9729	101.4027	33.80091

E-8; SHADING DEVICES

PU 3A	319.00	321.70	208.40	220.30	172.00	186.60	84.50	110.00
PU 3B	427.30	429.30	311.60	326.90	94.60	268.30	96.60	1485.60
PU 3C	275.60	280.50	218.50	232.20	176.80	192.90	83.00	110.10
PU 4B	2368.00	2374.00	1764.00	1854.00	1464.00	1574.00	650.20	846.10
PU 4C	1598.00	1627.00	1300.00	1382.00	1130.00	1236.00	503.00	660.60
PU 3A	199.30	265.00	157.00	187.00	128.00	143.00	89.00	67.00
PU 3B	270.70	360.00	213.00	254.00	174.00	194.00	121.00	91.20
PU 3C	177.20	235.00	152.00	180.00	126.00	139.00	90.20	67.70
PU 4B	1522.00	2022.00	1266.00	1442.00	987.00	1101.00	691.00	513.00
PU 4C	1063.00	1409.00	911.00	1082.00	756.00	835.00	541.00	406.00

E-9: ROOF SPRAY

ROOF SPRAY MMBTU	BUFFALO AIR	BUFFALO WATER	ST.LOUIS AIR	ST.LOUIS WATER	MEMPHIS AIR	MEMPHIS WATER	TAMPA AIR	TAMPA WATER
PU 2A	85.71	125.00	125.21	182.93	136.36	200.00	194.81	283.02
PU 2B	114.50	166.67	168.54	245.90	182.93	267.86	258.62	375.00
PU 2C	114.50	166.67	168.54	245.90	182.93	267.86	258.62	375.00
PU 3A	84.75	126.05	123.97	185.19	135.14	200.00	192.31	283.02
PU 3B	111.94	166.67	164.84	241.94	178.57	267.86	254.24	375.00
PU 3C	111.94	166.67	164.84	241.94	178.57	267.86	254.24	375.00
PU 4B	279.85	416.67	407.61	604.84	446.43	669.64	635.59	937.50
PU 4C	279.85	416.67	407.61	604.84	446.43	669.64	635.59	937.50
PU 5B	279.85	416.67	407.61	604.84	446.43	669.64	635.59	937.50
PU 5C	279.85	416.67	407.61	604.84	446.43	669.64	635.59	937.50

MMBTU	BUFFALO DECENT	BUFFALO COMP	ST.LOUIS DECENT	ST.LOUIS COMP	MEMPHIS DECENT	MEMPHIS COMP	TAMPA DECENT	TAMPA COMP
PU 2A	125.00	85.71	182.93	126.05	200.00	136.36	283.02	194.81
PU 2B	166.67	114.50	245.90	168.54	267.86	182.93	375.00	258.62
PU 2C	166.67	114.50	245.90	168.54	267.86	182.93	375.00	258.62
PU 3A	125.00	84.75	185.19	123.97	200.00	135.14	283.02	192.31
PU 3B	166.67	111.94	241.94	164.84	267.86	178.57	375.00	254.24
PU 3C	166.67	111.94	241.94	164.84	267.86	178.57	375.00	254.24
PU 4B	416.67	279.85	604.84	412.09	669.64	446.43	937.50	635.59
PU 4C	416.67	279.85	604.84	412.09	669.64	446.43	937.50	635.59
PU 5B	416.67	279.85	604.84	412.09	669.64	446.43	937.50	635.59

HVAC-1: REPLACE BURNER AND CONTROLS

REPLACE BURNER	BUF AIR/WAT	BUF COMP	ST.L AIR/WAT	ST.L COMP	MEM AIR/WAT	MEM COMP	TAM AIR/WAT	TAM COMP
PU 1A	27.89	NA	19.23	NA	14.57	NA	4.49	NA
PU 1B	19.54	NA	13.54	NA	8.63	NA	1.69	NA
PU 2A	122.22	NA	74.01	NA	-1.20	NA	10.18	NA
PU 2B	169.03	NA	84.06	NA	1.79	NA	0.68	NA
PU 2C	129.17	NA	88.91	NA	53.08	NA	12.07	NA
PU 3A	110.89	551.67	73.24	439.70	48.91	373.89	13.05	190.35
PU 3B	109.29	647.99	124.45	574.65	75.20	535.86	15.37	304.75
PU 3C	115.95	626.41	115.15	554.12	67.10	505.24	14.88	285.10
PU 4B	680.72	2917.70	379.26	2564.58	145.77	2104.86	34.25	1070.61
PU 4C	496.49	2734.93	284.84	2116.55	81.16	1849.59	28.20	1049.19
PU 5B	792.86	NA	663.55	NA	533.19	NA	32.98	NA
PU 5C	777.60	NA	654.13	NA	587.23	NA	38.74	NA

HVAC-2: REPLACE BOILER/FURNACE

REPLACE BOILER	BUFFALO AIR/WAT	BUFFALO COMPLEX	ST.LOUIS AIR/WAT	ST.LOUIS COMPLEX	MEMPHIS AIR/WAT	MEMPHIS COMPLEX	TAMPA AIR/WAT	TAMPA COMPLEX
PU 1A	47.27	NA	30.77	NA	21.49	NA	9.70	NA
PU 1B	27.98	NA	20.00	NA	14.01	NA	4.03	NA
PU 2A	179.27	NA	110.81	NA	30.50	NA	21.07	NA
PU 2B	260.54	NA	125.15	NA	33.52	NA	20.91	NA
PU 2C	289.71	NA	130.55	NA	87.51	NA	26.06	NA
PU 3A	257.53	963.03	112.25	702.56	74.55	595.44	28.18	307.78
PU 3B	290.82	1133.76	189.69	1012.36	119.21	902.28	33.18	470.24
PU 3C	264.15	1062.48	173.27	955.78	106.37	830.32	32.12	440.48
PU 4B	971.58	4765.49	565.32	4012.28	241.57	3321.98	73.34	1813.18
PU 4C	735.88	4260.51	427.48	3343.12	140.80	2988.73	61.06	1696.50
PU 5B	1138.19	NA	1050.77	NA	1151.21	NA	71.21	NA
PU 5C	1151.66	NA	1027.60	NA	1267.88	NA	83.64	NA

HVAC-3: VENT DAMPER

	BUFFALO AIR/WAT	BUFFALO COMPLEX	ST.LOUIS AIR/WAT	ST.LOUIS COMPLEX	MEMPHIS AIR/WAT	MEMPHIS COMPLEX	TAMPA AIR/WAT	TAMPA COMPLEX
PU 1A	12.57	NA	8.51	NA	6.23	NA	8.78	NA
PU 1B	8.40	NA	6.43	NA	5.05	NA	3.71	NA
PU 2A	53.02	NA	33.92	NA	6.54	NA	19.90	NA
PU 2B	87.57	NA	40.75	NA	9.05	NA	18.94	NA
PU 2C	95.17	NA	40.29	NA	32.04	NA	23.61	NA
PU 3A	79.15	269.52	31.83	173.36	23.49	141.69	25.53	62.04
PU 3B	87.63	313.16	59.77	394.10	40.83	259.52	30.06	115.46
PU 3C	80.28	286.88	55.35	281.98	36.43	222.85	29.10	107.81
PU 4B	293.16	1143.29	181.22	1023.36	86.63	774.51	66.98	365.46
PU 4C	216.61	984.77	134.96	774.35	52.35	662.98	55.31	341.94
PU 5B	340.37	NA	369.29	NA	521.43	NA	64.51	NA
PU 5C	335.71	NA	343.37	NA	574.27	NA	75.76	NA

HVAC-4: STACK HEAT RECLAIM

STACK ECON.	BUFFALO AIR/WAT	BUFFALO COMPLEX	ST.LOUIS AIR/WAT	ST.LOUIS COMPLEX	MEMPHIS AIR/WAT	MEMPHIS COMPLEX	TAMPA AIR/WAT	TAMPA COMPLEX
PU 1A	35.65	NA	23.56	NA	16.76	NA	5.33	NA
PU 1B	22.13	NA	15.62	NA	9.74	NA	2.25	NA
PU 2A	140.89	NA	85.69	NA	59.70	NA	12.08	NA
PU 2B	196.55	NA	97.63	NA	59.70	NA	11.50	NA
PU 2C	224.35	NA	101.88	NA	59.70	NA	14.33	NA
PU 3A	200.61	748.76	86.78	571.83	57.17	498.69	15.50	270.71
PU 3B	225.44	884.99	145.45	762.57	88.55	700.66	18.25	387.14
PU 3C	211.25	848.09	134.22	729.78	77.22	660.22	17.57	362.76
PU 4B	769.74	3957.78	439.69	3304.41	164.40	2309.94	40.67	1594.79
PU 4C	577.25	3623.86	330.85	2834.64	92.31	2549.45	33.58	1492.17
PU 5B	898.57	NA	757.56	NA	633.17	NA	39.17	NA
PU 5C	900.00	NA	760.95	NA	697.33	NA	46.00	NA

HVAC-5; REPLACE ELECTRIC RESISTANCE WITH HEAT PUMP

REPL.FLEC RES.W/H.P	BUFFALO DECENT	ST.LOUIS DECENT	MEMPHIS DECENT	TAMPA DECENT
PU 1A	46.87	39.06	28.31	-4.22
PU 1B	23.29	18.77	11.82	-4.46
PU 2A	145.45	97.60	17.49	-54.92
PU 2B	165.25	98.79	15.40	-55.66
PU 2C	190.36	120.26	53.91	-53.09
PU 3A	196.44	143.85	55.92	-51.10
PU 3B	234.92	177.96	99.60	-50.30
PU 3C	209.77	159.85	83.67	-48.26
PU 4B	753.34	418.91	14.42	-360.26
PU 4C	563.29	275.89	-108.94	-351.12
PU 5B	944.66	877.73	851.48	-303.56
PU 5C	991.36	906.95	956.58	-299.49

HVAC-6: BOILER TURBULATORS

BOILER TURBULATO	BUFFALO AIR/WAT	BUFFALO COMPLEX	ST.LOUIS AIR/WAT	ST.LOUIS COMPLEX	MEMPHIS AIR/WAT	MEMPHIS COMPLEX	TAMPA AIR/WAT	TAMPA COMPLEX
PU 1A	10.84	NA	6.74	NA	4.40	NA	NA	NA
PU 1B	5.50	NA	3.38	NA	2.03	NA	NA	NA
PU 2A	36.14	NA	20.35	NA	8.01	NA	2.42	NA
PU 2B	40.31	NA	20.44	NA	7.70	NA	2.30	NA
PU 2C	45.84	NA	23.81	NA	12.44	NA	2.87	NA
PU 3A	47.13	219.51	23.70	167.35	12.70	149.46	3.10	86.85
PU 3B	55.55	263.83	32.32	217.38	18.08	196.08	3.65	114.19
PU 3C	50.08	249.38	29.52	205.23	16.14	185.81	3.53	107.81
PU 4B	190.27	1186.48	96.00	947.85	35.23	847.89	8.13	511.62
PU 4C	148.95	1092.68	74.06	855.82	20.00	792.66	6.72	478.69
PU 5B	224.64	NA	155.00	NA	126.63	NA	7.83	NA
PU 5C	235.00	NA	159.90	NA	139.47	NA	9.20	NA

HVAC-7: MODULATING AQUASTAT

MODULAT. AQUASTAT	BUFFALO WATER	ST.LOUIS WATER	MEMPHIS WATER	TAMPA WATER
PU 1A	40.07	26.46	18.72	5.03
PU 1B	20.32	13.33	8.64	2.14
PU 2A	133.56	79.95	34.04	11.52
PU 2B	148.87	80.28	32.71	16.90
PU 2C	169.36	93.53	52.89	13.66
PU 3A	174.18	93.15	53.99	14.78
PU 3B	205.29	127.00	76.85	17.40
PU 3C	185.00	115.98	68.57	16.04
PU 4B	703.00	377.15	149.72	30.76
PU 4C	550.36	290.95	85.01	32.01
PU 5B	829.95	608.98	538.19	37.33
PU 5C	868.30	628.18	592.71	43.85

HVAC-9: ENTHALPY CONTROL

ENTHALPY CONTROL	BUFFALO AIR	ST.LOUIS AIR	MEMPHIS AIR	TAMPA AIR
PU 2A	483.64	471.45	487.07	342.41
PU 2B	507.46	497.09	513.92	361.16
PU 2C	552.06	540.36	559.03	392.55
PU 3A	555.77	538.33	560.58	392.74
PU 3B	675.91	661.11	688.48	482.53
PU 3C	650.11	630.82	667.47	460.34
PU 4B	3325.96	3198.87	3329.59	2332.47
PU 4C	3164.52	3009.79	3195.66	2193.90
PU 5B	2802.09	2737.27	2840.19	1983.86
PU 5C	2846.36	2784.63	2889.78	2018.60

HVAC-8: INSTALL SETBACK THERMOSTATS MMBTU SAVINGS

SETBACK THERMOSTA	RUF AIR/WAT	RUF DECENT	ST.L AIR/WAT	ST.L DECENT	MEM AIR/WAT	MEM DECENT	TAM AIR/WAT	TAM DECENT
PU 1A	35.24	23.89	24.40	16.13	23.34	14.78	8.47	2.82
PU 1B	20.27	12.61	14.74	8.52	15.27	7.81	4.47	1.49
PU 2A	150.89	95.56	107.57	64.54	98.58	59.15	33.90	11.30
PU 2B	170.82	93.00	110.85	62.82	101.58	57.56	33.00	11.00
PU 2C	183.30	101.83	114.63	68.78	126.05	63.03	36.13	12.04
PU 3A	174.22	104.53	109.56	70.60	111.97	64.70	37.09	12.36
PU 3B	178.09	108.83	127.23	73.51	126.30	67.36	38.61	12.87
PU 3C	185.50	113.36	132.52	76.57	131.55	70.16	40.22	13.41
PU 4B	717.74	446.60	522.07	301.64	540.80	276.41	150.45	52.82
PU 4C	730.21	462.46	535.48	312.36	585.47	286.23	164.08	54.69
PU 5B	719.21	447.51	578.79	302.26	830.92	276.97	158.77	52.92
PU 5C	747.13	473.18	587.02	319.60	878.58	292.86	167.88	55.96
	COMP		COMP		COMP		COMP	
PU 1A	33.07		22.34		20.47		3.91	
PU 1B	17.46		11.80		10.81		2.07	
PU 2A	132.32		89.37		81.89		15.65	
PU 2B	128.78		86.98		79.70		15.23	
PU 2C	141.00		95.23		87.27		16.68	
PU 3A	144.74		97.76		89.58		17.12	
PU 3B	150.69		101.78		93.27		17.82	
PU 3C	156.96		106.01		97.14		18.56	
PU 4B	618.36		417.68		382.72		73.13	
PU 4C	640.34		432.50		396.32		75.73	
PU 5B	619.63		418.51		383.50		73.20	
PU 5C	655.17		442.52		405.50		77.48	

HVAC-10: REPLACE ROOM AIR CONDITIONERS

REPLACE ROOM AC	BUFFALO WAT/DEC	ST.LOUIS WAT/DEC	MEMPHIS WAT/DEC	TAMPA WAT/DEC
PU 1A	10.17	21.94	25.02	39.09
PU 1B	6.37	13.13	14.67	23.04
PU 2A	66.52	128.07	142.72	220.88
PU 2B	65.89	126.55	140.98	217.83
PU 2C	68.33	133.11	148.66	230.66
PU 3A	69.48	67.72	151.98	234.57
PU 3B	72.55	143.05	160.72	248.71
PU 3C	70.98	138.18	157.88	239.57
PU 4B	391.10	730.40	813.08	1245.05
PU 4C	379.80	695.03	787.64	1177.44
PU 5B	308.06	618.72	696.77	1078.30
PU 5C	313.49	634.16	715.03	1107.65

HVAC-11: REPLACE CENTRAL AIR CONDITIONING

REPLACE CENT.A/C	BUFFALO AIR/COMP	ST.LOUIS AIR/COMP	MEMPHIS AIR/COMP	TAMPA AIR/COMP
PU 1A	2.44	5.26	5.99	9.36
PU 1B	1.53	3.15	3.52	5.52
PU 2A	13.95	26.86	29.93	46.32
PU 2B	13.82	26.54	29.57	45.68
PU 2C	14.33	27.92	31.18	48.37
PU 3A	14.59	14.22	31.92	49.26
PU 3B	15.23	30.04	33.75	52.23
PU 3C	14.91	29.02	33.15	50.31
PU 4B	82.13	153.38	170.74	261.45
PU 4C	79.75	145.95	165.40	247.25
PU 5B	64.69	129.93	146.32	226.44
PU 5C	65.83	133.17	150.15	232.60

HVAC-12: VARY CHILLED WATER TEMPERATURE WITH LOAD

VARY CHW W/LOAD	BUFFALO AIR/REC	BUFFALO AIR/CENT	ST.LOUIS AIR/REC	ST.LOUIS AIR/CENT	MEMPHIS AIR/REC	MEMPHIS AIR/CENT	TAMPA AIR/REC	TAMPA AIR/CENT
PU 2A	15.87	42.17	24.96	69.06	23.35	66.56	34.13	98.16
PU 2B	19.38	49.04	37.24	94.23	41.51	105.00	64.14	162.26
PU 2C	20.09	50.85	39.15	99.07	43.72	110.63	67.84	171.66
PU 3A	20.21	51.04	19.69	49.75	44.20	111.65	68.21	172.33
PU 3B	21.10	53.30	41.61	105.10	46.75	118.09	72.34	182.73
PU 3C	20.64	52.15	40.18	101.51	45.91	115.99	69.67	176.00
PU 4B	114.07	287.94	213.02	537.74	237.13	598.61	363.12	916.65
PU 4C	110.75	279.58	202.66	511.62	229.67	579.80	343.32	866.73
PU 5B	89.66	226.46	180.09	454.85	202.80	512.21	313.85	792.69
PU 5C	91.25	230.46	184.59	466.21	208.13	525.65	322.41	814.29

HVAC-13: CONVERT REHEAT SYSTEM TO VARIABLE AIR VOLUME

CONVERT REH-VAV	BUFFALO COMPLEX	ST.LOUIS COMPLEX	MEMPHIS COMPLEX	TAMPA COMPLEX
PU 3A	3976.82	3478.27	3312.33	2677.95
PU 3B	4800.37	4453.70	4275.67	3384.81
PU 3C	4584.49	4227.70	4081.94	3219.54
PU 4B	22758.7	20467.7	19520.9	16030.9
PU 4C	21456.4	18805.1	18534.9	15148.9

HVAC-14: REDUCE VENTILATION VOLUME

REDUCE VENT.VOL.	BUFFALO AIR	ST.LOUIS AIR	MEMPHIS AIR	BUFFALO AIR
PU 2A	31.57	25.11	19.13	10.05
PU 2B	36.53	26.38	20.02	10.05
PU 2C	35.82	25.11	22.15	10.05
PU 3A	626.27	444.44	368.50	186.68
PU 3B	737.05	590.44	475.12	225.75
PU 3C	710.91	565.29	461.64	216.09
PU 4B	3653.65	2932.30	2442.13	1120.21
PU 4C	3433.83	2752.21	2440.73	1059.93
PU 5B	513.48	452.47	498.49	158.93
PU 5C	504.80	436.19	498.49	158.93

HVAC-15: EVAPORATIVE COOLING

EVAPOR. COOLING	BUFFALO AIR	ST.LOUIS AIR	MEMPHIS AIR	TAMPA AIR
PU 2A	310.36	311.27	196.27	225.27
PU 2B	325.17	327.66	206.75	237.22
PU 2C	352.89	355.35	224.35	257.23
PU 3A	355.89	354.74	225.40	257.85
PU 3B	430.56	433.28	275.32	315.07
PU 3C	414.53	413.91	267.12	300.93
PU 4B	2136.91	2115.47	1343.62	1536.90
PU 4C	2036.56	1994.52	1291.35	1448.60
PU 5B	1897.58	1906.06	1207.53	1377.44
PU 5C	1925.09	1936.36	1226.88	1399.58

HVAC-16: CONVERT AIR-COOLED CONDENSER TO WATER-COOLED

CONVERT AC-WC CONDENS.	BUF RECIP	BUF CENT	ST.L RECIP	ST.L CENT	MEM RECIP	MEM CENT	TAM RECIP	TAM CENT
PU 2A	19.62	6.31	39.52	13.12	41.23	12.46	60.73	18.45
PU 2B	19.44	6.25	39.05	12.96	40.73	12.31	59.89	18.19
PU 2C	20.16	6.48	41.08	13.63	42.94	12.98	63.42	19.26
PU 3A	20.13	6.48	20.53	6.81	43.13	13.04	63.35	19.24
PU 3B	21.02	6.76	43.36	14.39	45.61	13.79	67.17	20.40
PU 3C	20.57	6.62	41.89	13.90	44.80	13.54	64.70	19.65
PU 4B	113.33	36.46	221.41	73.48	230.71	69.75	336.26	102.14
PU 4C	110.05	35.40	210.69	69.92	223.50	67.56	318.00	96.59
PU 5B	89.26	28.72	187.55	62.25	197.71	59.77	291.23	88.46
PU 5C	90.84	29.22	192.23	63.80	202.89	61.33	299.16	90.87

CONVERT AC-WC $/MMBTU	BUF RECIP	BUF CENT	ST.L RECIP	ST.L CENT	MEM RECIP	MEM CENT	TAM RECIP	TAM CENT
PU 2A	184.98	574.99	91.85	276.75	88.05	291.25	59.77	196.78
PU 2B	186.75	580.49	92.95	280.08	89.13	294.85	60.61	199.53
PU 2C	180.10	559.80	88.37	266.26	84.53	279.63	57.24	188.44
PU 3A	356.63	1108.53	349.76	1053.87	166.49	550.73	113.33	373.10
PU 3B	341.56	1061.69	165.58	498.91	157.44	520.79	106.89	351.90
PU 3C	349.09	1085.10	171.41	516.49	160.28	530.18	110.97	365.32
PU 4B	285.02	885.93	145.88	439.56	140.00	463.11	96.06	316.23
PU 4C	293.50	912.30	153.31	461.93	144.52	478.07	101.57	334.39
PU 5B	142.84	443.99	67.98	204.83	64.49	213.32	43.78	144.13
PU 5C	140.36	436.29	66.33	199.85	62.84	207.88	42.62	140.31

HVAC-17: FOG COOLING

COOLING	BUFFALO AIR/COMP	ST.LOUIS AIR/COMP	MEMPHIS AIR/COMP	TAMPA AIR/COMP
PU 2A	387.09	561.79	569.53	850.81
PU 2B	405.56	591.37	599.94	895.93
PU 2C	440.13	641.35	651.01	971.49
PU 3A	443.87	640.25	654.06	973.85
PU 3B	537.01	781.99	798.89	1189.95
PU 3C	517.01	747.03	775.10	1136.54
PU 4B	2665.22	3818.06	3898.79	5804.51
PU 4C	2540.06	3599.78	3747.13	5471.02
PU 5B	2366.72	3440.13	3503.89	5202.28
PU 5C	2401.03	3494.81	3560.05	5285.90

HVAC-18: INSULATE DUCTS

INSULATE DUCTS	BUF AIR	BUF COMP	ST.L AIR	ST.L COMP	MEM AIR	MEM COMP	TAM AIR	TAM COMP
PU 1A	26.77	25.27	23.28	21.65	21.10	19.19	50.28	27.86
PU 1B	13.84	12.12	12.18	10.31	10.76	8.54	21.03	12.35
PU 2A	110.75	99.92	92.68	83.35	68.46	63.89	153.24	56.77
PU 2B	100.19	79.93	95.59	82.47	70.64	63.66	143.74	92.34
PU 2C	111.01	89.80	105.03	94.02	91.55	74.80	168.79	165.77
PU 3A	300.04	253.50	255.85	231.52	239.80	202.14	420.53	227.10
PU 3B	361.45	310.03	292.28	243.52	269.01	211.63	323.29	184.17
PU 3C	352.91	302.73	281.32	234.39	261.45	205.83	327.34	184.68
PU 4B	1887.21	1647.23	1453.01	1211.83	1232.03	943.18	1314.26	781.48
PU 4C	1846.63	1638.79	1368.37	1151.00	1157.03	857.40	1297.14	764.56
PU 5B	616.64	546.32	483.74	392.17	259.32	197.22	754.69	466.93
PU 5C	645.52	580.48	506.77	421.96	327.96	230.86	840.54	509.53

HVAC-19: INSULATE PIPES

INSULATE PIPES	BUFFALO WATER	ST.LOUIS WATER	MEMPHIS WATER	TAMPA WATER
PU 1A	4.00	2.86	2.36	3.31
PU 1B	3.04	2.08	1.53	2.12
PU 2A	19.80	13.03	8.06	11.95
PU 2B	14.49	12.19	7.61	10.41
PU 2C	15.21	13.21	8.87	11.63
PU 3A	17.02	15.45	11.95	12.31
PU 3B	17.38	12.28	10.23	7.33
PU 3C	17.62	12.38	10.23	7.80
PU 4B	75.80	50.84	36.92	23.81
PU 4C	79.25	51.22	34.33	25.10
PU 5B	73.83	41.36	9.97	40.73
PU 5C	77.77	44.77	14.40	45.70

HVAC-20: TWO-SPEED FAN MOTORS

2-SPEED MOTORS	BUFFALO AIR	ST.LOUIS AIR	MEMPHIS AIR	TAMPA AIR
PU 1A	21.07	13.98	9.95	-0.65
PU 1B	10.66	7.00	4.56	-2.15
PU 2A	79.41	48.29	22.13	2.60
PU 2B	83.67	47.91	21.19	1.88
PU 2C	94.38	55.16	32.10	1.74
PU 3A	101.55	59.71	37.15	1.98
PU 3B	117.41	73.93	47.14	4.11
PU 3C	107.46	68.51	42.99	6.36
PU 4B	390.95	215.06	94.07	8.78
PU 4C	316.45	172.16	60.37	9.21
PU 5B	445.74	321.72	273.25	14.02
PU 5C	466.53	332.74	302.35	6.43

DHW-1: SUMMER DHW HEATER

SUMMER DHW HTR	BUFFALO	ST.LOUIS	MEMPHIS	TAMPA
PU 1A	2.55	3.68	3.78	5.62
PU 1B	2.55	3.68	3.78	5.62
PU 2A	40.64	58.53	60.15	89.41
PU 2B	40.64	58.53	60.15	89.41
PU 2C	40.64	58.53	60.15	89.41
PU 3A	NA	NA	NA	NA
PU 3B	NA	NA	NA	NA
PU 3C	NA	NA	NA	NA
PU 4B	NA	NA	NA	NA
PU 4C	NA	NA	NA	NA
PU 5B	352.01	506.89	520.97	774.41
PU 5C	352.01	506.89	520.97	774.41

DHW-2: FLOW CONTROLS

FLOW CONTROL	BUFFALO	ST.LOUIS	MEMPHIS	TAMPA
PU 1A	14.30	14.30	14.30	14.30
PU 1B	14.30	14.30	14.30	14.30
PU 2A	209.98	209.98	209.98	209.98
PU 2B	209.98	209.98	209.98	209.98
PU 2C	209.98	209.98	209.98	209.98
PU 3A	4.02	3.10	3.02	1.51
PU 3B	4.02	3.10	3.02	1.51
PU 3C	59.12	45.57	44.34	22.17
PU 4B	59.12	45.57	44.34	22.17
PU 4C	59.12	45.57	44.34	22.17
PU 5B	1244.33	1244.33	1244.33	1244.33
PU 5C	1244.33	1244.33	1244.33	1244.33

DHW-3: INSULATE STORAGE TANK MMBTU SAVINGS

INSULATE DHW TANK	BUF AIR	BUF WAT	ST.L AIR	ST.L WAT	MEM AIR	MEM WAT	TAM AIR	TAM WAT
PU 1A	6.15	6.35	6.80	7.10	6.81	7.10	7.31	7.74
PU 1B	5.98	6.18	6.60	6.90	6.44	6.74	7.31	7.74
PU 2A	167.10	174.30	184.70	195.00	186.62	197.19	202.38	218.11
PU 2B	157.60	164.80	182.00	192.00	183.91	194.49	202.38	218.11
PU 2C	158.90	166.10	185.00	195.00	177.43	188.01	202.38	218.11
PU 3A	13.25	13.25	9.50	9.50	10.32	10.32	8.95	8.95
PU 3B	13.00	13.00	10.60	10.60	11.18	11.18	8.95	8.95
PU 3C	13.00	13.00	10.60	10.60	11.18	11.18	8.95	8.95
PU 4B	45.30	45.30	37.60	37.60	41.37	41.37	31.72	31.72
PU 4C	44.50	44.50	37.30	37.30	43.25	43.25	31.72	31.72
PU 5B	1050.00	1104.00	1134.00	1213.00	929.49	1010.41	1314.91	1435.19
PU 5C	1057.00	1112.00	1151.00	1230.00	929.49	1010.41	1314.91	1435.19

	DECENT	COMPLEX	DECENT	COMPLEX	DECENT	COMPLEX	DECENT	COMPLEX
PU 1A	6.96	6.27	7.60	6.93	7.65	6.99	8.70	8.08
PU 1B	6.96	6.27	7.60	6.93	7.65	6.99	8.70	8.08
PU 2A	195.50	174.22	213.89	192.71	215.57	194.39	245.67	224.64
PU 2B	195.50	174.22	213.89	192.71	215.57	194.39	245.67	224.64
PU 2C	195.50	174.22	213.89	192.71	215.57	194.39	245.67	224.64
PU 3A	7.95	11.01	6.13	8.49	5.96	8.26	2.98	4.13
PU 3B	7.95	11.01	6.13	8.49	5.96	8.26	2.98	4.13
PU 3C	7.95	11.01	6.13	8.49	5.96	8.26	2.98	4.13
PU 4B	28.19	39.04	21.73	30.09	21.14	29.28	10.57	14.64
PU 4C	28.19	39.04	21.73	30.09	21.14	29.28	10.57	14.64
PU 5B	1268.66	1109.86	1404.17	1245.18	1416.49	1257.48	1638.23	1478.90
PU 5C	1268.66	1109.86	1404.17	1245.18	1416.49	1257.48	1638.23	1478.90

DHW-4: DHW VENT DAMPER

```
DHW VENT
DAMPER    ALL ZONES
           AND SYS.

PU 1A          5.58
PU 1B          5.58
PU 2A         76.48
PU 2B         76.48
PU 2C         76.48
PU 3A         29.05
PU 3B         29.05
PU 3C         29.05
PU 4B        180.14
PU 4C        180.14
PU 5B        339.64
PU 5C        339.64
```

DHW-5: DHW HEAT PUMP

```
DHW
HEAT PUMP

PU 1A      19.20918
PU 1B      19.20918
PU 3A      280.9245
PU 2B      280.9245
PU 2C      280.9245
PU 3A      103.5771
PU 3B      103.5771
PU 3C      103.5771
PU 4B      667.4928
PU 4C      667.4928
PU 5B      1621.705
PU 5C      1621.705
```

L-1: REPLACE INCANDESCENT LIGHTS WITH FLUORESCENT MMBTU SAVINGS

REPLACE INC.W/FLR	BUF AIR	BUF WAT	ST.L AIR	ST.L WAT	MEM AIR	MEM WAT	TAM AIR	TAM WAT
PU 1A	8.70	1.40	9.00	4.50	9.00	4.40	8.90	6.40
PU 1B	8.60	0.50	8.90	3.30	8.90	2.50	8.90	6.40
PU 2A	134.00	10.20	138.00	56.80	139.00	61.90	141.00	99.40
PU 2B	132.00	-17.60	137.00	48.60	138.00	53.90	141.00	99.40
PU 2C	132.00	-13.60	138.00	56.80	136.00	34.60	141.00	99.40
PU 3A	863.00	5.50	898.00	430.00	893.00	365.50	918.00	643.00
PU 3B	865.00	25.70	889.00.	332.00	885.00	290.00	913.00	643.00
PU 3C	865.00	25.70	889.00	332.00	885.00	290.00	913.00	643.00
PU 4B	5246.00	~~278.00~~	5379.00	~~2012.00~~	5335.00	~~1501.00~~	5524.00	~~3890.00~~
PU 4C	5246.00	~~400.00~~	5389.00	~~2067.00~~	5312.00	~~1222.00~~	5523.00	~~3890.00~~
PU 5B	1043.00	~~55.20~~	1058.00	~~281.00~~	1001.00	~~-353.00~~	1098.00	~~773.00~~
PU 5C	1044.00	~~79.50~~	1064.00	~~331.00~~	1000.00	~~-361.00~~	1098.00	~~773.00~~
	DECENT	COMP	DECENT	COMP	DECENT	COMP	DECENT	COMP
PU 1A	4.69	1.48	7.23	4.38	7.45	4.65	11.61	9.42
PU 1B	4.69	1.48	7.23	4.38	7.45	4.65	11.61	9.42
PU 2A	72.97	20.73	112.43	65.02	115.84	68.99	180.57	141.67
PU 2B	72.97	20.73	112.43	65.02	115.84	68.99	180.57	141.67
PU 2C	72.97	20.73	112.43	65.02	115.84	68.99	180.57	141.67
PU 3A	472.06	132.25	727.38	416.96	749.42	442.67	1168.22	911.06
PU 3B	472.06	132.25	727.38	416.96	749.42	442.67	1168.22	911.06
PU 3C	472.06	132.25	727.38	416.96	749.42	442.67	1168.22	911.06
PU 4B	2856.59	800.29	4401.60	2523.14	4534.98	2678.75	7069.24	5513.12
PU 4C	2855.83	800.08	4400.42	2522.47	4533.77	2678.04	7067.35	5511.64
PU 5B	567.78	159.07	874.86	501.50	901.38	532.43	1405.09	1095.79
PU 5C	567.78	159.07	874.86	501.50	901.38	532.43	1405.09	1095.79

L-2: INSTALL FLUORESCENT HYBRID LAMPS MMBTU SAVINGS

FLUORESC.	BUF AIR	BUF WAT	ST.L AIR	ST.L WAT	MEM AIR	MEM WAT	TAM AIR	TAM WAT
PU 1A	4.10	0.60	4.20	2.10	4.20	2.08	4.18	3.00
PU 1B	4.00	0.20	4.20	1.60	4.10	1.16	4.18	3.00
PU 2A	84.50	6.40	86.80	35.70	87.10	38.93	88.93	62.50
PU 2B	82.90	-11.10	86.20	30.50	86.60	33.93	88.93	62.50
PU 2C	83.00	-8.60	86.80	35.70	65.50	21.78	88.93	62.50
PU 3A	828.00	5.30	861.00	412.00	856.00	350.37	880.32	616.22
PU 3B	829.00	24.70	8852.00	319.00	849.00	278.18	875.04	616.22
PU 3C	829.00	24.70	852.00	319.00	849.00	278.18	875.04	616.22
PU 4B	5018.00	~~266.00~~	5146.00	~~1924.00~~	5103.00	~~1435.27~~	5283.91	~~3721.08~~
PU 4C	5028.00	~~303.00~~	5155.00	~~1977.00~~	5081.00	~~1169.26~~	5282.92	~~3720.36~~
PU 5B	708.00	~~37.50~~	718.00	~~180.00~~	679.00	~~-238.85~~	745.04	~~524.68~~
PU 5C	708.00	~~53.90~~	722.00	~~225.00~~	679.00	~~-244.78~~	744.81	~~524.51~~
	DECENT	COMP	DECENT	COMP	DECENT	COMP	DECENT	COMP
PU 1A	2.20	0.69	3.39	2.05	3.49	2.18	5.45	4.42
PU 1B	2.20	0.69	3.39	2.05	3.49	2.18	5.45	4.42
PU 2A	45.89	13.04	70.71	40.89	72.85	43.39	113.57	89.10
PU 2B	45.89	13.04	70.71	40.89	72.85	43.39	113.57	89.10
PU 2C	45.89	13.04	70.71	40.89	72.85	43.39	113.57	89.10
PU 3A	452.49	126.77	697.21	399.67	718.34	424.31	1119.77	873.28
PU 3B	452.49	126.77	697.21	399.67	718.34	424.31	1119.77	873.28
PU 3C	452.49	126.77	697.21	399.67	718.34	424.31	1119.77	873.28
PU 4B	2732.32	765.48	4210.11	2413.37	4337.69	2562.22	6761.70	5273.27
PU 4C	2731.81	765.33	4209.33	2412.92	4336.88	2561.74	6760.43	5272.29
PU 5B	385.26	107.93	593.64	340.29	611.63	361.28	953.42	743.55
PU 5C	385.26	107.93	593.64	340.29	611.63	361.28	953.42	743.55

L-3: USE LOW-WATTAGE TASK LIGHTING

	BUF AIR	BUF WAT	ST.L AIR	ST.L WAT	MEN AIR	MEN WAT	TAM AIR	TAM WAT
PU 3A	171.32	1.09	178.24	85.29	177.15	72.54	182.25	127.58
PU 3B	171.68	5.10	176.42	65.98	175.69	57.59	181.16	127.58
PU 3C	171.68	5.10	176.42	65.98	175.69	57.59	181.16	127.58
PU 4B	928.87	49.20	952.48	356.20	944.61	265.67	978.06	688.78
PU 4C	930.83	70.85	954.45	366.04	940.67	216.47	978.06	688.78
	DECENT	COMP	DECENT	COMP	DECENT	COMP	DECENT	COMP
PU 3A	93.68	26.24	144.35	82.74	148.72	87.85	231.83	180.80
PU 3B	93.68	26.24	144.35	82.74	148.72	87.85	231.83	180.80
PU 3C	93.68	26.24	144.35	82.74	148.72	87.85	231.83	180.80
PU 4B	505.76	141.69	779.30	446.72	802.92	474.27	1251.81	976.10
PU 4C	505.76	141.69	779.30	446.72	802.92	474.27	1251.61	976.10

L-4: INSTALL HIGH-EFFICIENCY FLUORESCENT LAMPS

HI-EFFIC. FLUORES.	BUF AIR	BUF WAT	ST.L AIR	ST.L WAT	MEN AIR	MEN WAT	TAM AIR	TAM WAT
PU 3A	67.27	0.43	69.99	33.49	69.56	28.48	71.57	50.10
PU 3B	67.42	2.00	69.28	25.91	68.99	22.61	71.14	50.10
PU 3C	67.42	2.00	69.78	25.91	68.99	22.61	71.14	50.10
PU 4B	405.94	21.50	416.26	155.67	412.82	116.11	427.44	301.01
PU 4C	406.80	30.96	417.12	159.97	411.10	94.60	427.44	301.01
	DECENT	COMP	DECENT	COMP	DECENT	COMP	DECENT	COMP
PU 3A	36.78	10.31	56.68	32.49	58.40	34.49	91.03	70.99
PU 3B	36.78	10.31	56.68	32.49	58.40	34.49	91.03	70.99
PU 3C	36.78	10.31	56.68	32.49	58.40	34.49	91.03	70.99
PU 4B	221.03	61.92	340.58	195.23	350.90	207.27	546.99	426.58
PU 4C	221.03	61.92	340.58	195.23	350.90	207.27	546.99	426.58

Section J: Cost/Savings Ratios without Fuel Factor Adjustment for 41 Building Types in Four Climate Zones

These tables present the capital costs (unamortized) per million Btus of annual savings for all building types analyzed in all four climate zones. The ratios in the lists in this section treat savings in electricity and fuel alike with no allowance for the difference in prices. These numbers must be multiplied by the fuel cost adjustment factors in Section K to be equivalent to the cost/savings ratios in the lists in Sections E and F.

APPENDIX A

Non-Interactive Cost/Savings Ratios for Each Conservation Measure, Organized by Climate Zone and Building Type

A.1 Introduction

The aggregate data results of Phase III of the calculation method (see Section 2.0) are presented in Table 8 on the following 20 pages. For each climate zone, conservation measures are listed vertically and building structural/mechanical/usage types listed horizontally. Usage types are noted by number, as follows:

1 = Single family

2 = Small family

3 = Small commercial

4 = Large commercial

5 = Large multifamily

The table presents the cost per million Btu's of base energy savings for each conservation measure. These results are not adjusted for interaction or fuel type. Therefore, they represent the ratio of cost to savings of Btu's consumed at the boundary of the building, regardless of fuel type, as if each measure were implemented by itself before any of the other measures listed were implemented.

LABEL	TABLE 8-1 BUFFALO (1) MEASURE	CAV/AIR/1	CAV/H20/1	CAV/DEC/1	MBW/AIR/1	MBW/H20/1	MBW/DEC/1	CAV/AIR/2	CAV/H20/2	CAV/DEC/2
E-1	ROOF/ATTIC INS.	14	14	20	22	22	35	79	78	123
E-2	WALL INSUL.	6.5	6.5	9.4	112	110	171	6.2	6.1	9.4
E-3	STORM WINDOWS	25	24	35	20	20	30	21	21	32
E-4	DOUBLE GLAZING	101	100	144	81	81	124	85	85	130
E-5	WEATHERSTRIPPIN	8.7	8.6	12	6.0	5.9	9.4	25	25	38
E-6	WINDOW INSUL.	43	43	63	39	39	63	40	40	63
E-7	REFLECT. FILMS									
E-8	SHADING DEVICES									
E-9	ROOF SPRAYS							18	12	12
H-1	REPLACE BURNER	34	34		38	38		23	23	
H-2	REPLACE BOILER		37			50			25	
H-3	VENT DAMPER	9.0	9.0		13	13		5.3	3.5	
H-4	STACK HT. RECL.		25			38			9.9	
H-5	ELEC. HEAT PUMP			131			209			190
H-6	BOILER TURBUL.								51	
H-7	MODUL.AQUASTAT		6.2			12			3.0	
H-8	THERMOSTATS	3.8	3.8		6.7	6.7	10.7	7.2	7.2	11.3
H-9	ENTHALPY CONTR.							4.3		
H10	REPLACE ROOM AC		87	87		140	140		89	89
H11	REPLACE CENT.AC	738			1048			688		
H12	VARY CHW TEMP.							141		
H13	REHEAT-VAV									
H14	REDUCE VENTIL.									
H15	EVAP. COOLING									
H16	WATER-CL.CONDEN							185		
H17	FOG COOLING									
H18	INSULATE DUCTS	54			68			50		
H19	INSULATE PIPES		125			165			117	
H20	2-SPEED FAN MOT	5.0			7.2			5.0		
D-1	SUMMER DHW HTR.								30	
D-2	FLOW CONTROLS	1.3	1.3	1.3	1.3	1.3	1.3	0.8	0.8	0.8
D-3	INSULATE STORAG	4.9	4.7	4.3	5.0	4.9	4.3	2.7	2.6	2.3
D-4	DHW VENT DAMPER	27	27	27	27	27	27	2.6	2.6	2.6
D-5	DHW HEAT PUMP	51	51	118	51	51	118	9.0	9.0	21
L-1	INCAN.-FLUOR.							11	25	19
L-2	HYBRID LAMPS	24	49	46	25	55	46	1.6	42	29
L-3	TASK LIGHTING									
L-4	HI-EFFIC.FLUOR.									

TABLE 8-1
BUFFALO (2)

LABEL	MEASURE	MBW/AIR/2	MBW/H20/2	MBW/DEC/2	CLAD/AIR/2	CLAD/H20/2	CLAD/DEC/2	CAV/AIR/3	CAV/H20/3	CAV/DEC/3
E-1	ROOF/ATTIC INS.	49	48	87	49	49	87	74	73	122
E-2	WALL INSUL.	99	97	172	88	86	150	5.9	5.8	9.4
E-3	STORM WINDOWS	18	18	32				20	19	31
E-4	DOUBLE GLAZING	74	74	130	36	35	61	77	77	124
E-5	WEATHERSTRIPPIN	22	21	38	30	29	51	28	28	45
E-6	WINDOW INSUL.	34	34	63	29	29	51	38	38	63
E-7	REFLECT. FILMS							28	27	40
E-8	SHADING DEVICES							16	16	26
E-9	ROOF SPRAYS	13	9.0	9.0	13	9.0	9.0	18	12	12
H-1	REPLACE BURNER	20	20		26	26		32	32	
H-2	REPLACE BOILER		32			29			34	
H-3	VENT DAMPER	4.0	2.7		3.5	2.3		4.3	2.8	
H-4	STACK HT. RECL.		9.2			8.0			9.1	
H-5	ELEC. HEAT PUMP			278			242			273
H-6	BOILER TURBUL.		92			82			88	
H-7	MODUL.AOUASTAT		2.7			2.4			2.3	
H-8	THERMOSTATS	6.3	6.3	12	5.9	5.9	11	6.2	6.2	10
H-9	ENTHALPY CONTR.	4.1			3.7			4.3		
H10	REPLACE ROOM AC		90	90		87	87		170	170
H11	REPLACE CENT.AC	695			670			1611		
H12	VARY CHW TEMP.	115			111			129		
H13	REHEAT-VAV									
H14	REDUCE VENTIL.							0.4		
H15	EVAP. COOLING									
H16	WATER-CL.CONDEN	187			180			357		
H17	FOG COOLING									
H18	INSULATE DUCTS	56			56			39		
H19	INSULATE PIPES		160			153			136	
H20	2-SPEED FAN MOT	5.0			4.4			4.8		
D-1	SUMMER DHW HTR.		30			30				
D-2	FLOW CONTROLS	0.8	0.8	0.8	0.8	0.8	0.8	2.0	2.0	2.0
D-3	INSULATE STORAG	2.9	2.7	2.3	2.8	2.7	2.3	12	12	21
D-4	DHW VENT DAMPER	2.6	2.6	2.6	2.6	2.6	2.6	5.2	5.2	5.2
D-5	DHW HEAT PUMP	9.0	9.0	21	9.0	9.0	21			
L-1	INCAN.-FLUOR.	11	29	19	11	25	19	45	95	82
L-2	HYBRID LAMPS	16	56	29	16	45	29	21	50	38
L-3	TASK LIGHTING							60	80	109
L-4	HI-EFFIC.FLUOR.							32	70	58

TABLE 8-1
BUFFALO (3)

LABEL	MEASURE	CAV/COMP/3	MBW/AIR/3	MBW/H20/3	MBW/DEC/3	MBW/COMP/3	CLAD/AIR/3	CLAD/H20/3	CLAD/DEC/3	CLAD/COMP/3
E-1	ROOF/ATTIC INS.	74	72	53	87	72	55	54	87	72
E-2	WALL INSUL.	7.0	110	109	172	130	96	95	150	113
E-3	STORM WINDOWS	23	15	14	23	17				
E-4	DOUBLE GLAZING	93	37	37	59	44	39	39	61	46
E-5	WEATHERSTRIPPIN	34	12	12	18	14	18	18	27	21
E-6	WINDOW INSUL.	38	31	31	51	31	31	31	51	31
E-7	REFLECT. FILMS	30	26	25	40	30	26	26	40	40
E-8	SHADING DEVICES	19	12	12	20	15	15	15	24	18
E-9	ROOF SPRAYS	18	13	9.0	9.0	13	13	9.0	9.0	13
H-1	REPLACE BURNER	6.3	33	33		5.6	30	30		6.0
H-2	REPLACE BOILER	9.0		32		8.4		32		7.9
H-3	VENT DAMPER	0.8	4.0	2.7		0.7	4.3	2.8		0.8
H-4	STACK HT. RECL.	2.4		8.3		2.1		8.6		2.2
H-5	ELEC. HEAT PUMP				265				256	
H-6	BOILER TURBUL.	19		86		18		83		17
H-7	MODUL.AOUASTAT			2.0				2.2		
H-8	THERMOSTATS	7.5	6.1	6.1	9.9	7.2	5.8	5.8	9.5	6.9
H-9	ENTHALPY CONTR.		3.6				3.7			
H10	REPLACE ROOM AC			164	164			167	167	
H11	REPLACE CENT.AC	1611	1543			1543	1577			1577
H12	VARY CHW TEMP.		123				126			
H13	REHEAT-VAV	0.8				0.7				0.7
H14	REDUCE VENTIL.		0.4				0.4			
H15	EVAP. COOLING									
H16	WATER-CL.CONDEN	357	342			342	349			349
H17	FOG COOLING									
H18	INSULATE DUCTS	46	37			43	33			38
H19	INSULATE PIPES			133				132		
H20	2-SPEED FAN MOT		4.2				4.5			
D-1	SUMMER DHW HTR.									
D-2	FLOW CONTROLS	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
D-3	INSULATE STORAG	15	13	13	21	15	13	13	21	15
D-4	DHW VENT DAMPER	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2
D-5	DHW HEAT PUMP									
L-1	INCAN.-FLUOR.	105	45	110	82	105	45	110	82	105
L-2	HYBRID LAMPS	50	21	45	38	50	21	28	38	50
L-3	TASK LIGHTING	150	60	97	109	50	60	95	109	150
L-4	HI-EFFIC.FLUOR.	70	31	55	45	70	31	55	45	70

LABEL	TABLE 8-1 BUFFALO (4) MEASURE	MBW/AIR/4	MBW/H20/4	MBW/DEC/4	MBW/COMP/4	CLAD/AIR/4	CLAD/H20/4	CLAD/DEC/4	CLAD/COMP/	MBW/AIR/5
E-1	ROOF/ATTIC INS.	55	55	87	72	57	55	87	72	55
E-2	WALL INSUL.	112	110	172	130	100	98	150	115	112
E-3	STORM WINDOWS									
E-4	DOUBLE GLAZING	27	27	43	32	41	40	61	46	40
E-5	WEATHERSTRIPPIN	14	14	22	17	26	26	40	30	40
E-6	WINDOW INSUL.	32	32	51	32	33	33	51	33	32
E-7	REFLECT. FILMS	23	23	40	30	23	23	40	30	
E-8	SHADING DEVICES	13	13	20	15	16	16	24	18	
E-9	ROOF SPRAYS	13	9.0	9.0	13	13	9.0	9.0	13	13
H-1	REPLACE BURNER	10	10		2.3	11	11		1.9	5.8
H-2	REPLACE BOILER		35		7.3		30		5.1	
H-3	VENT DAMPER	2.3	1.5		0.3	3.0	2.0		0.5	1.5
H-4	STACK HT. RECL.	8.6	8.6		1.7	9.5	9.5		1.5	
H-5	ELEC. HEAT PUMP			252				248		
H-6	BOILER TURBUL.		84		13		73		9.9	
H-7	MODUL.AOUASTAT		0.8				1.0			
H-8	THERMOSTATS	6.0	6.0	9.7	7.0	5.9	5.9	9.3	6.8	6.0
H-9	ENTHALPY CONTR.	0.9				1.0				1.0
H10	REPLACE ROOM AC		194	194			200	200		
H11	REPLACE CENT.AC	1530			1530	1575			1575	680
H12	VARY CHW TEMP.	28				29				36
H13	REHEAT-VAV				0.4				0.4	
H14	REDUCE VENTIL.	0.3				0.3				
H15	EVAP. COOLING									
H16	WATER-CL.CONDEN	285			285	294			294	143
H17	FOG COOLING									
H18	INSULATE DUCTS	25			39	24			28	42
H19	INSULATE PIPES		95				91			
H20	2-SPEED FAN MOT	2.7				3.2				2.0
D-1	SUMMER DHW HTR.									
D-2	FLOW CONTROLS	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1.3
D-3	INSULATE STORAG	13	13	21	21	13	13	21	15	3.2
D-4	DHW VENT DAMPER	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	0.7
D-5	DHW HEAT PUMP									8.6
L-1	INCAN.-FLUOR.	44	65	60	50	44	70	50	50	14
L-2	HYBRID LAMPS	15	50	28	45	15	45	28	40	13
L-3	TASK LIGHTING	73	115	95	90	73	115	95	90	

LABEL	TABLE 8-1 BUFFALO (5) MEASURE	MBW/H20/5	MBW/DEC/5	CLAD/AIR/5	CLAD/H20/5	CLAD/DEC/5				
E-1	ROOF/ATTIC INS.	55	87	57	55	87				
E-2	WALL INSUL.	110	172	100	98	150				
E-3	STORM WINDOWS									
E-4	DOUBLE GLAZING	39	61	41	40	61				
E-5	WEATHERSTRIPPIN	39	61	40	40	61				
E-6	WINDOW INSUL.	32	51	33	33	51				
E-7	REFLECT. FILMS									
E-8	SHADING DEVICES									
E-9	ROOF SPRAYS	9.0	9.0	13	9.0	9.0				
H-1	REPLACE BURNER	5.8		6.0	6.0					
H-2	REPLACE BOILER	12			12					
H-3	VENT DAMPER	1.0		1.5	1.0					
H-4	STACK HT. RECL.	4.9			4.9					
H-5	ELEC. HEAT PUMP		114			109				
H-6	BOILER TURBUL.	35			35					
H-7	MODUL.AOUASTAT	0.6			0.6					
H-8	THERMOSTATS	6.0	9.7	5.8	5.8	9.1				
H-9	ENTHALPY CONTR.			1.0						
H10	REPLACE ROOM AC	129	129		126	126				
H11	REPLACE CENT.AC			668						
H12	VARY CHW TEMP.			35						
H13	REHEAT-VAV									
H14	REDUCE VENTIL.									
H15	EVAP. COOLING									
H16	WATER-CL.CONDEN			140						
H17	FOG COOLING									
H18	INSULATE DUCTS			40						
H19	INSULATE PIPES	97			92					
H20	2-SPEED FAN MOT			2.0						
D-1	SUMMER DHW HTR.	30			30					
D-2	FLOW CONTROLS	1.3	1.3	1.3	1.3	1.3				
D-3	INSULATE STORAG	3.0	2.6	3.2	3.0	2.6				
D-4	DHW VENT DAMPER	0.7	0.7	0.7	0.7	0.7				
D-5	DHW HEAT PUMP	8.6	17	8.6	8.6	17				
L-1	INCAN.-FLUOR.	30	26	14	30	26				
L-2	HYBRID LAMPS	28	24	13	28	24				
L-3	TASK LIGHTING									
L-4	HI-EFFIC.FLUOR.									

TABLE 8-2
ST. LOUIS (1)

LABEL	MEASURE	CAV/AIR/1	CAV/H20/1	CAV/DEC/1	MBW/AIR/1	MBW/H20/1	MBW/DEC/1	CAV/AIR/2	CAV/H20/2	CAV/DEC/2
E-1	ROOF/ATTIC INS.	18	17	24	28	26	41	98	93	144
E-2	WALL INSUL.	8.3	7.9	11	137	131	200	7.7	7.3	11
E-3	STORM WINDOWS	34.1	32.4	44.7	27.0	25.9	39.8	29	27	41
E-4	DOUBLE GLAZING	140	134	184	110	107	165	118	112	166
E-5	WEATHERSTRIPPIN	15.5	14.9	20.8	10.2	9.8	15.4	42	40	60
E-6	WINDOW INSUL.	61.9	61.9	93.6	54.1	54.1	93.6	56	56	94
E-7	REFLECT. FILMS									
E-8	SHADING DEVICES									
E-9	ROOF SPRAYS							12	8.2	8.2
H-1	REPLACE BURNER	45.8	45.8		52.8	52.8		36	36	
H-2	REPLACE BOILER		53			66			41	
H-3	VENT DAMPER	13.2	13.2		17.5	17.5		8.3	5.5	
H-4	STACK HT. RECL.		37.2			51.2			14	
H-5	ELEC. HEAT PUMP			141			196			249
H-6	BOILER TURBUL.								80	
H-7	MODUL. AOUASTAT		9.5			18.8			5.0	
H-8	THERMOSTATS	5.5	5.5		9.2	9.2	15.9	10	10	17
H-9	ENTHALPY CONTR.							4.4		
H10	REPLACE ROOM AC		41	41		68	68		46	46
H11	REPLACE CENT.AC	343			509			357		
H12	VARY CHW TEMP.							89		
H13	REHEAT-VAV									
H14	REDUCE VENTIL.									
H15	EVAP. COOLING									
H16	WATER-CL.CONDEN							92		
H17	FOG COOLING									
H18	INSULATE DUCTS	53			67			51		
H19	INSULATE PIPES		176			241			178	
H20	2-SPEED FAN MOT	7.5			11			8.0		
D-1	SUMMER DHW HTR.								21	
D-2	FLOW CONTROLS	1.3	1.3	1.3	1.3	1.3	1.3	0.8	0.8	0.8
D-3	INSULATE STORAG	4.4	4.2	4.0	4.6	4.4	4.0	2.4	2.3	2.1
D-4	DHW VENT DAMPER	26.9	26.9	26.9	26.9	26.9	26.9	2.6	2.6	2.6
D-5	DHW HEAT PUMP	51	51	118	51	51	118	9	9	21
L-1	INCAN.-FLUOR.							10	25	13
L-2	HYBRID LAMPS	23.8	47.6	29.5	23.8	62.5	29.5	16	38	19
L-3	TASK LIGHTING									

TABLE 8-2
ST. LOUIS (2)

LABEL	MEASURE	MBW/AIR/2	MBW/H20/2	MBW/DEC/2	CLAD/AIR/2	CLAD/H20/2	CLAD/DEC/2	CAV/AIR/3	CAV/H20/3	CAV/DEC/3
E-1	ROOF/ATTIC INS.	67	63	101	71	66	101	104	97	143
E-2	WALL INSUL.	137	129	200	125	118	175	8.3	7.7	11
E-3	STORM WINDOWS	27	26	41				30	28	39
E-4	DOUBLE GLAZING	112	107	166	51	48	71	118	112	157
E-5	WEATHERSTRIPPIN	40	38	60	50	48	72	54	51	73
E-6	WINDOW INSUL.	53	53	94	46	46	77	60	60	94
E-7	REFLECT. FILMS							36	35	48
E-8	SHADING DEVICES							22	22	31
E-9	ROOF SPRAYS	8.9	6.1	6.1	8.9	6.1	6.1	12	8.1	8.1
H-1	REPLACE BURNER	35	35		33	33		40	40	
H-2	REPLACE BOILER		36			36			49	
H-3	VENT DAMPER	7.0	4.7		7.0	4.7		8.8	5.8	
H-4	STACK HT. RECL.		12			12.3			14.4	
H-5	ELEC. HEAT PUMP			246			230			195
H-6	BOILER TURBUL.		90			80			92	
H-7	MODUL.AQUASTAT		5.0			4.3			4.3	
H-8	THERMOSTATS	9.7	9.7	17	9.4	9.4	16	9.9	9.9	15
H-9	ENTHALPY CONTR.	4.1			3.8			4.5		
H10	REPLACE ROOM AC		46	46		44	44		175	175
H11	REPLACE CENT.AC	362			344			1653		
H12	VARY CHW TEMP.	60			57			132		
H13	REHEAT-VAV									
H14	REDUCE VENTIL.							0.6		
H15	EVAP. COOLING									
H16	WATER-CL.CONDEN	93			88			350		
H17	FOG COOLING									
H18	INSULATE DUCTS	54			54			31		
H19	INSULATE PIPES		190			176			150	
H20	2-SPEED FAN MOT	8.1			7.1			7.4		
D-1	SUMMER DHW HTR.		21			21				
D-2	FLOW CONTROLS	0.8	0.8	0.8	0.8	0.8	0.8	2.6	2.6	2.6
D-3	INSULATE STORAG	2.5	2.3	2.1	2.4	2.3	2.1	17	17	27
D-4	DHW VENT DAMPER	2.6	2.6	2.6	2.6	2.6	2.6	5.2	5.2	5.2
D-5	DHW HEAT PUMP	9	9	21	9	9	21			
L-1	INCAN.-FLUOR.	10	29	13	10	25	13	43	90	53
L-2	HYBRID LAMPS	16	44	19	16	38	19	20	42	25
L-3	TASK LIGHTING							57	80	71
L-4	HI-EFFIC.FLUOR.							30	63	37

TABLE 8-2
ST. LOUIS (3)

LABEL	MEASURE	CAV/COMP/3	MBW/AIR/3	MBW/H20/3	MBW/DEC/3	MBW/COMP/3	CLAD/AIR/3	CLAD/H20/3	CLAD/DEC/3	CLAD/COMP/
E-1	ROOF7ATTIC INS.	104	92	65	102	92	69	65	102	92
E-2	WALL INSUL.	9.1	139	131	200	169	121	114	175	147
E-3	STORM WINDOWS	33	20	19	29	24				
E-4	DOUBLE GLAZING	132	51	49	75	63	49	47	71	60
E-5	WEATHERSTRIPPIN	60	19	18	28	23	30	30	46	36
E-6	WINDOW INSUL.	60	44	44	77	44	44	44	77	44
E-7	REFLECT. FILMS	39	32	31	48	39	33	32	48	48
E-8	SHADING DEVICES	26	16	15	25	20	16	17	27	22
E-9	ROOF SPRAYS	12	9.1	6.2	6.2	9.1	9.1	6.2	6.2	9.1
H-1	REPLACE BURNER	6.6	27	27		5.8	29	29		6.0
H-2	REPLACE BOILER	7.8		44		8.4		48		8.6
H-3	VENT DAMPER	1.0	5.8	3.8		0.7	6.3	4.2		0.8
H-4	STACK HT. RECL.	2.2		13		2.4		14		2.5
H-5	ELEC. HEAT PUMP				301				302	
H-6	BOILER TURBUL.	13		128		19		133		19
H-7	MODUL.AOUASTAT			3.2				3.5		
H-8	THERMOSTATS	11	8.5	8.5	15	11	8.2	8.2	14	10
H-9	ENTHALPY CONTR.		3.6				3.8			
H10	REPLACE ROOM AC			82	82			86	86	
H11	REPLACE CENT.AC	1653	782			782	810			810
H12	VARY CHW TEMP.		62				65			
H13	REHEAT-VAV	0.9				0.7				0.7
H14	REDUCE VENTIL.		0.5				0.5			
H15	EVAP. COOLING									
H16	WATER-CL.CONDEN	350	166			166	171			171
H17	FOG COOLING									
H18	INSULATE DUCTS	34	39			47	36			44
H19	INSULATE PIPES			189				188		
H20	2-SPEED FAN MOT		6.6				7.1			
D-1	SUMMER DHW HTR.									
D-2	FLOW CONTROLS	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6
D-3	INSULATE STORAG	19	16	16	27	19	16	16	27	19
D-4	DHW VENT DAMPER	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2
D-5	DHW HEAT PUMP									
L-1	INCAN.-FLUOR.	93	43	116	53	93	43	116	53	93
L-2	HYBRID LAMPS	43	20	54	25	43	20	28	25	43
L-3	TASK LIGHTING	123	58	90	71	124	58	90	71	124

TABLE 8-2
ST. LOUIS (4)

LABEL	MEASURE	MBW/AIR/4	MBW/H20/4	MBW/DEC/4	MBW/COMP/4	CLAD/AIR/4	CLAD/H20/4	CLAD/DEC/4	CLAD/COMP/	MBW/AIR/5.
E-1	ROOF/ATTIC INS.	69	65	102	92	70	65	102	72	60
E-2	WALL INSUL.	139	131	200	162	122	115	175	147	128
E-3	STORM WINDOWS									
E-4	DOUBLE GLAZING	37	35	54	45	50	4[illegible]	71	60	45
E-5	WEATHERSTRIPPIN	23	22	34	28	46	44	71	56	59
E-6	WINDOW INSUL.	44	44	77	44	45	45	77	45	40
E-7	REFLECT. FILMS	32	30	48	39	33	32	48	39	
E-8	SHADING DEVICES	16	15	24	20	18	17	27	22	
E-9	ROOF SPRAYS	9.2	6.2	6.2	9.1	9.2	6.2	6.2	9.1	9.2
H-1	REPLACE BURNER	15	15		2.2	18	18		2.4	6.5
H-2	REPLACE BOILER		47		6.6		38		4.8	
H-3	VENT DAMPER	3.5	2.3		0.3	4.8	3.2		0.5	1.3
H-4	STACK HT. RECL.	13	13		1.7	15	15		1.7	
H-5	ELEC. HEAT PUMP			371				432		
H-6	BOILER TURBUL.		128		13		120		10	
H-7	MODUL.AOUASTAT		1.4				1.8			
H-8	THERMOSTATS	8.3	8.3	14	10	8.1	8.1	14	10	7.5
H-9	ENTHALPY CONTR.	0.9				1.0				1.0
H10	REPLACE ROOM AC		104	104			110	110		
H11	REPLACE CENT.AC	819			819	860			860	338
H12	VARY CHW TEMP.	15				16				18
H13	REHEAT-VAV				0.4				0.5	
H14	REDUCE VENTIL.	0.3				0.3				
H15	EVAP. COOLING									
H16	WATER-CL.CONDEN	149			149	153			153	68
H17	FOG COOLING									
H18	INSULATE DUCTS	32			53	32			39	54
H19	INSULATE PIPES		141				140			
H20	2-SPEED FAN MOT	4.8				5.7				2.9
D-1	SUMMER DHW HTR.									
D-2	FLOW CONTROLS	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1.3
D-3	INSULATE STORAG	16	16	27	27	16	16	27	20	3.0
D-4	DHW VENT DAMPER	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	0.7
D-5	DHW HEAT PUMP									8.6
L-1	INCAN.-FLUOR.	43	64	53	46	43	66	46	46	14
L-2	HYBRID LAMPS	15	40	18	32	15	39	18	32	13
L-3	TASK LIGHTING	71	108	87	80	71	108	87	80	
L-4	HI-EFFIC.FLUOR.	81	50	37	40	31	50	37	40	

LABEL	TABLE 8-2 ST. LOUIS (5) MEASURE	MBW/H20/5	MBW/DEC/5	CLAD/AIR/5	CLAD/H20/5	CLAD/DEC/5				
E-1	ROOF/ATTIC.INS.	60	102	65	62	102				
E-2	WALL INSUL.	121	200	115	109	175				
E-3	STORM WINDOWS									
E-4	DOUBLE GLAZING	43	71	47	44	71				
E-5	WEATHERSTRIPPIN	57	97	62	59	97				
E-6	WINDOW INSUL.	50	77	42	42	77				
E-7	REFLECT. FILMS									
E-8	SHADING DEVICES									
E-9	ROOF SPRAYS	6.2	6.2	9.2	6.2	6.2				
H-1	REPLACE BURNER	6.5		6.7	6.7					
H-2	REPLACE BOILER	11.6			13.2					
H-3	VENT DAMPER	0.8		1.5	1.0					
H-4	STACK HT. RECL.	4.2			4.3					
H-5	ELEC. HEAT PUMP		123			119				
H-6	BOILER TURBUL.	43			45					
H-7	MODUL.AOUASTAT	0.9			0.9					
H-8	THERMOSTATS	7.5	14	7.4	7.4	14				
H-9	ENTHALPY CONTR.			1.0						
H10	REPLACE ROOM AC	64	64	331	62	62				
H11	REPLACE CENT.AC			17						
H12	VARY CHW TEMP.									
H13	REHEAT-VAV									
H14	REDUCE VENTIL.									
H15	EVAP. COOLING									
H16	WATER-CL.CONDEN			66						
H17	FOG COOLING									
H18	INSULATE DUCTS			52						
H19	INSULATE PIPES	174			160					
H20	2-SPEED FAN MOT			2.7						
D-1	SUMMER DHW HTR.	21			21					
D-2	FLOW CONTROLS	1.3	1.3	1.3	1.3	1.3				
D-3	INSULATE STORAG	2.8	2.4	2.9	2.7	2.4				
D-4	DHW VENT DAMPER	0.7	0.7	0.7	0.7	0.7				
D-5	DHW HEAT PUMP	8.6	17	8.6	8.6	17				
L-1	INCAN.-FLUOR.	24	17	14	24	17				
L-2	HYBRID LAMPS	22	16	13	22	16				
L-3	TASK LIGHTING									

LABEL	TABLE 8-3 MEMPHIS (1) MEASURE	CAV/AIR/1	CAV/H20/1	CAV/DEC/1	MBW/AIR/1	MBW/H20/1	MBW/DEC/1	CAV/AIR/2	CAV/H20/2	CAV/DEC/2
E-1	ROOF/ATTIC INS.	22	21	29	33	31	50	129	118	173
E-2	WALL INSUL.	10	9.7	13	163	153	242	10	9.4	13
E-3	STORM WINDOWS	43.2	40.2	32.5	32.5	30.6	26.6	38	35	27
E-4	DOUBLE GLAZING	177	166	225	133	127	202	157	145	205
E-5	WEATHERSTRIPPIN	20.4	19.3	26.8	12.8	12.0	20.2	57	53	77
E-6	WINDOW INSUL.	83.1	83.1	131	67.0	67.0	131	79	79	131
E-7	REFLECT. FILMS									
E-8	SHADING DEVICES									
E-9	ROOF SPRAYS							11	7.5	7.5
H-1	REPLACE BURNER	51.5	51.5		71.8	71.8		36	36	
H-2	REPLACE BOILER		65			82			126	
H-3	VENT DAMPER	18.1	18.1		22.3	22.3		43	28	
H-4	STACK HT. RECL.		52.2			77.0			18	
H-5	ELEC. HEAT PUMP			172			274			1052
H-6	BOILER TURBUL.								167	
H-7	MODUL.AQUASTAT		13.4			29.0			12	
H-8	THERMOSTATS	5.8	5.8		8.8	8.8	17.3	11	11	18
H-9	ENTHALPY CONTR.							4.2		
H10	REPLACE ROOM AC		36	36		61	61		42	42
H11	REPLACE CENT.AC	300			455			321		
H12	VARY CHW TEMP.							96		
H13	REHEAT-VAV									
H14	REDUCE VENTIL.									
H15	EVAP. COOLING									
H16	WATER-CL.CONDEN							88		
H17	FOG COOLING									
H18	INSULATE DUCTS	47			60			54		
H19	INSULATE PIPES		213			328			288	
H20	2-SPEED FAN MOT	10.4			17			16		
D-1	SUMMER DHW HTR.								20	
D-2	FLOW CONTROLS	1.3	1.3	1.3	1.3	1.3	1.3	0.8	0.8	0.8
D-3	INSULATE STORAG	4.4	4.2	3.9	4.7	4.5	3.9	2.4	2.3	2.1
D-4	DHW VENT DAMPER	26.9	26.9	26.9	26.9	26.9	26.9	2.6	2.6	2.6
D-5	DHW HEAT PUMP	51	51	118	51	51	118	9	9	21
L-1	INCAN.-FLUOR.							10	23	12
L-2	HYBRID LAMPS	23.8	48.1	28.6	24.4	86.5	28.6	16	35	19
L-3	TASK LIGHTING									
L-4	HI-EFFIC.FLUOR.									

LABEL	TABLE 8-3 MEMPHIS (2) MEASURE	MBW/AIR/2	MBW/H20/2	MBW/DEC/2	CLAD/AIR/2	CLAD/H20/2	CLAD/DEC/2	CAV/AIR/3	CAV/H20/3	CAV/DEC/3
E-1	ROOF/ATTIC INS.	89	81	121	80	74	121	125	114	172
E-2	WALL INSUL.	180	165	242	142	131	210	10	9.1	13
E-3	STORM WINDOWS	37	34	30	58			36	33	48
E-4	DOUBLE GLAZING	150	139	205	59	53	86	143	132	192
E-5	WEATHERSTRIPPIN	55	51	77	54	56	92	68	63	93
E-6	WINDOW INSUL.	74	74	131		54	107	76	76	131
E-7	REFLECT. FILMS							46	43	59
E-8	SHADING DEVICES							27	26	39
E-9	ROOF SPRAYS	8.2	5.6	5.6	8.2	5.6	5.6	11	7.5	7.5
H-1	REPLACE BURNER	43	43		43	43		48	48	
H-2	REPLACE BOILER		121			49			60	
H-3	VENT DAMPER	31	21		8.8	5.8		12	8	
H-4	STACK HT. RECL.		18			20			21	
H-5	ELEC. HEAT PUMP			1195			408			393
H-6	BOILER TURBUL.		190			121			124	
H-7	MODUL.AOUASTAT		12			7.6			7.4	
H-8	THERMOSTATS	11	11	19	8.6	8.6	17	9.7	9.7	17
H-9	ENTHALPY CONTR.	4.0			3.7			4.3		
H10	REPLACE ROOM AC		42	42		40	40		78	78
H11	REPLACE CENT.AC	325			308			736		
H12	VARY CHW TEMP.	54			51			59		
H13	REHEAT-VAV									
H14	REDUCE VENTIL.							0.7		
H15	EVAP. COOLING									
H16	WATER-CL.CONDEN	89			85			166		
H17	FOG COOLING									
H18	INSULATE DUCTS	58			58			33		
H19	INSULATE PIPES		305			262			194	
H20	2-SPEED FAN MOT	17			62			11.3		
D-1	SUMMER DHW HTR.		20			20				
D-2	FLOW CONTROLS	0.8	0.8	0.8	0.8	0.8	0.8	2.7	2.7	2.7
D-3	INSULATE STORAG	2.5	2.3	2.1	2.5	2.3	2.1	16	16	28
D-4	DHW VENT DAMPER	2.6	2.6	2.6	2.6	2.6	2.6	5.2	5.2	5.2
D-5	DHW HEAT PUMP	9	9	21	9	9	21			
L-1	INCAN.-FLUOR.	10	26	12	10	20	12	43	106	52
L-2	HYBRID LAMPS	16	40	19	16	32	19	20	49	24
L-3	TASK LIGHTING							55	80	69
[illegible]	[illegible]							30	74	36

LABEL	TABLE 8-3 MEMPHIS (3) MEASURE	CAV/COMP/3	MBW/AIR/3	MBW/H20/3	MBW/DEC/3	MBW/COMP/3	CLAD/AIR/3	CLAD/H20/3	CLAD/DEC/3	CLAD/COMP/3
E-1	ROOF/ATTIC INS.	125	118	78	122	118	85	78	122	118
E-2	WALL INSUL.	11.9	172	158	242	219	150	137	210	190
E-3	STORM WINDOWS	43	25	23	36	32				
E-4	DOUBLE GLAZING	172	168	59	91	82	61	56	86	78
E-5	WEATHERSTRIPPIN	81	25	23	36	32	37	34	54	47
E-6	WINDOW INSUL.	76	57	57	107	57	57	57	107	57
E-7	REFLECT. FILMS	51	33	36	59	51	45	41	59	59
E-8	SHADING DEVICES	33	42	19	30	26	22	21	33	29
E-9	ROOF SPRAYS	11	8.4	5.6	5.6	8.4	8.4	5.6	5.6	8.4
H-1	REPLACE BURNER	6.3	43	43		6.0	47	47		6.2
H-2	REPLACE BOILER	7.6		62		8.2		64		8.2
H-3	VENT DAMPER	1.3	7.0	4.7		0.8	7.8	5.2		0.8
H-4	STACK HT. RECL.	2.4		21		2.6		22		2.6
H-5	ELEC. HEAT PUMP				431				457	
H-6	BOILER TURBUL.	11		186		17		174		15
H-7	MODUL.AQUASTAT			5.2				5.8		
H-8	THERMOSTATS	12	8.6	8.6	16	12	8.2	8.2	15	11
H-9	ENTHALPY CONTR.		3.5				3.6			
H10	REPLACE ROOM AC			73	73			76	76	
H11	REPLACE CENT.AC	736	696			696	709			709
H12	VARY CHW TEMP.		56				57			
H13	REHEAT-VAV	0.9				0.7				0.7
H14	REDUCE VENTIL.		0.7				0.6			
H15	EVAP. COOLING									
H16	WATER-CL.CONDEN	166	157			157	160			160
H17	FOG COOLING									
H18	INSULATE DUCTS	39	36			45	36			45
H19	INSULATE PIPES			227				227		
H20	2-SPEED FAN MOT		9.8				10.5			
D-1	SUMMER DHW HTR.									
D-2	FLOW CONTROLS	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
D-3	INSULATE STORAG	20	15	15	2.8	20	15	15	28	20
D-4	DHW VENT DAMPER	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2
D-5	DHW HEAT PUMP									
L-1	INCAN.-FLUOR.	87	44	133	52	87	44	133	52	87
L-2	HYBRID LAMPS	40	20	62	24	40	20	28	24	40
L-3	TASK LIGHTING	116	58	85	69	117	58	85	69	117
L-4	HI-EFFIC.FLUOR.	61	31	45	36	61	31	45	36	61

TABLE 8-3

MEMPHIS (4)

LABEL	MEASURE	MBW/AIR/4	MBW/H2O/4	MBW/DEC/4	MBW/COMP/4	CLAD/AIR/4	CLAD/H2O/4	CLAD/DEC/4	CLAD/COMP/	MBW/AIR/5
E-1	ROOF/ATTIC INS.	82	76	122	118	79	73	122	118	57
E-2	WALL INSUL.	166	153	242	219	140	129	219	190	116
E-3	STORM WINDOWS									
E-4	DOUBLE GLAZING	44	41	66	59	57	52	56	78	41
E-5	WEATHERSTRIPPIN	29	27	44	38	51	48	82	71	55
E-6	WINDOW INSUL.	55	55	107	55	52	52	107	52	36
E-7	REFLECT. FILMS	38	39	59	52	38	36	59	52	
E-8	SHADING DEVICES	19	18	30	26	21	19	33	29	
E-9	ROOF SPRAYS	8.4	5.6	5.6	8.4	8.4	5.6	5.6	8.4	8.4
H-1	REPLACE BURNER	36	36		25	55	55		2.4	6.9
H-2	REPLACE BOILER		67		4.9		9.1		4.4	
H-3	VENT DAMPER	7.3	4.8		0.5	9.5	6.3		0.5	0.8
H-4	STACK HT. RECL.	29	29		1.7	47	47		1.7	
H-5	ELEC. HEAT PUMP			5548						
H-6	BOILER TURBUL.		261		11		387		9.8	
H-7	MODUL.AQUASTAT		3.6							
H-8	THERMOSTATS	8.0	8.0	16	11	7.4	6.3	15	11	5.2
H-9	ENTHALPY CONTR.	0.9				0.9	7.4			1.0
H10	REPLACE ROOM AC		94	94				96		
H11	REPLACE CENT.AC	736			736	760	96		760	301
H12	VARY CHW TEMP.	13				14				16
H13	REHEAT-VAV				0.5				0.5	
H14	REDUCE VENTIL.	0.4				0.4				
H15	EVAP. COOLING									
H16	WATER-CL.CONDEN	140			140	145			145	64
H17	FOG COOLING									
H18	INSULATE DUCTS	38			67	39			5.2	99
H19	INSULATE PIPES		194				209			
H20	2-SPEED FAN MOT	9.9				14				3.5
D-1	SUMMER DHW HTR.									
D-2	FLOW CONTROLS	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1.3
D-3	INSULATE STORAG	14	14	28	28	14	14	28	20	3.6
D-4	DHW VENT DAMPER	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	0.7
D-5	DHW HEAT PUMP									8.6
L-1	INCAN.-FLUOR.	44	62	51	44	44	64	44	44	15
L-2	HYBRID LAMPS	15	30	15	30	15	30	15	30	14
L-3	TASK LIGHTING	71	105	85	75	71	105	85	75	

LABEL	TABLE 8-3 MEMPHIS (5) MEASURE	MBW/H20/5	MBW/DEC/5	CLAD/AIR/5	CLAD/H20/5	CLAD/DEC/5				
E-1	ROOF/ATTIC INS.	54	122	57	54	122				
E-2	WALL INSUL.	109	242	101	95	210				
E-3	STORM WINDOWS									
E-4	DOUBLE GLAZING	39	86	41	39	86				
E-5	WEATHERSTRIPPIN	53	122	55	53	122				
E-6	WINDOW INSUL.	36	107	36	36	107				
E-7	REFLECT. FILMS									
E-8	SHADING DEVICES									
E-9	ROOF SPRAYS	5.6	5.6	8.4	5.6	5.6				
H-1	REPLACE BURNER	6.9		6.3	6.3					
H-2	REPLACE BOILER	9.1			8.3					
H-3	VENT DAMPER	0.5		1.5	0.3					
H-4	STACK HT. RECL.	3.0			2.7					
H-5	ELEC. HEAT PUMP		92			82				
H-6	BOILER TURBUL.	39			36					
H-7	MODUL.AOUASTAT	1.0			0.9					
H-8	THERMOSTATS	5.2	16	4.9	4.9	15				
H-9	ENTHALPY CONTR.			1.0						
H10	REPLACE ROOM AC	56	56		55	55				
H11	REPLACE CENT.AC			293						
H12	VARY CHW TEMP.			15						
H13	REHEAT-VAV									
H14	REDUCE VENTIL.									
H15	EVAP. COOLING									
H16	WATER-CL.CONDEN			63						
H17	FOG COOLING									
H18	INSULATE DUCTS			79						
H19	INSULATE PIPES	720			499					
H20	2-SPEED FAN MOT			3.2						
D-1	SUMMER DHW HTR.	21			21					
D-2	FLOW CONTROLS	1.3	1.3	1.3	1.3	1.3				
D-3	INSULATE STORAG	3.3	2.4	3.6	3.3	2.4				
D-4	DHW VENT DAMPER	0.7	0.7	0.7	0.7	0.7				
D-5	DHW HEAT PUMP	8.6	17	8.6	8.6	17				
L-1	INCAN.-FLUOR.	21	17	15	21	17				
L-2	HYBRID LAMPS	20	15	14	20	15				
L-3	TASK LIGHTING									

LABEL	TABLE 8-4 TAMPA (1) MEASURE	CAV/AIR/1	CAV/H20/1	CAV/DEC/1	MBW/AIR/1	MBW/H20/1	MBW/DEC/1	CAV/AIR/2	CAV/H20/2	CAV/DEC/2
E-1	ROOF/ATTIC INS.	39	32	40	68	55	70	247	190	242
E-2	WALL INSUL.	18	15	18	338	277	338	19	15	18
E-3	STORM WINDOWS	77.9	63.7	78.0	70.1	57.4	73.0	75	58	71
E-4	DOUBLE GLAZING	320	262	322	286	235	291	308	240	294
E-5	WEATHERSTRIPPIN	40.7	33.3	50.0	30.0	25.0	30.0	123	95	118
E-6	WINDOW INSUL.	304	304	912	304	304	912	304	304	912
E-7	REFLECT. FILMS									
E-8	SHADING DEVICES									
E-9	ROOF SPRAYS							7.7	5.3	5.3
H-1	REPLACE BURNER	127	127		274	274		118	118	
H-2	REPLACE BOILER		109						164	
H-3	VENT DAMPER	26	26		61	61		103	18	
H-4	STACK HT. RECL.		141			311			79	
H-5	ELEC. HEAT PUMP									
H-6	BOILER TURBUL.								321	
H-7	MODUL.AOUASTAT		49			117			35	
H-8	THERMOSTATS	15.9	15.9		30.2	30.2	90.5	32	32	96
H-9	ENTHALPY CONTR.							6.0		
H10	REPLACE ROOM AC		23	23		39	39		27	27
H11	REPLACE CENT.AC	192			290			207		
H12	VARY CHW TEMP.							65		
H13	REHEAT-VAV									
H14	REDUCE VENTIL.									
H15	EVAP. COOLING									
H16	WATER-CL.CONDEN							59		
H17	FOG COOLING									
H18	INSULATE DUCTS	30			49			49		
H19	INSULATE PIPES		266			416			341	
H20	2-SPEED FAN MOT	12			22			11		
D-1	SUMMER DHW HTR.								14	
D-2	FLOW CONTROLS	1.3	1.3	1.3	1.3	1.3	1.3	0.8	0.8	0.8
D-3	INSULATE STORAG	4.1	3.9	3.5	4.1	3.9	3.5	2.2	2.1	1.8
D-4	DHW VENT DAMPER	26.9	26.9	26.9	26.9	26.9	26.9	2.6	2.6	2.6
D-5	DHW HEAT PUMP	51	51	118	51	51	118	9	9	21
L-1	INCAN.-FLUOR.							10	14	7.8
L-2	HYBRID LAMPS	23.9	33.8	18.4	23.9	33.4	18.4	15	22	12
L-3	TASK LIGHTING									

LABEL	TABLE 8-4 TAMPA (2) MEASURE	MBW/AIR/2	MBW/H20/2	MBW/DEC/2	CLAD/AIR/2	CLAD/H20/2	CLAD/DEC/2	CAV/AIR/3	CAV/H20/3	CAV/DEC/3
E-1	ROOF/ATTIC INS.	177	136	170	177	136	170	247	188	241
E-2	WALL INSUL.	359	277	340	312	241	294	19	15	18
E-3	STORM WINDOWS	75	58	71				73	56	69
E-4	DOUBLE GLAZING	308	240	294	127	98	120	291	224	274
E-5	WEATHERSTRIPPIN	123	95	118	147	113	140	152	116	144
E-6	WINDOW INSUL.	304	304	912	249	249	746	304	304	912
E-7	REFLECT. FILMS							88	73	92
E-8	SHADING DEVICES							56	45	61
E-9	ROOF SPRAYS	5.8	4.0	4.0	5.8	4.0	4.0	7.8	5.3	5.3
H-1	REPLACE BURNER	129	129		104	104		96	96	
H-2	REPLACE BOILER		160			110			98	
H-3	VENT DAMPER	55	20		25	17		22	15	
H-4	STACK HT. RECL.		83			66			61	
H-5	ELEC. HEAT PUMP									
H-6	BOILER TURBUL.		339			293			326	
H-7	MODUL.AQUASTAT		36			29			27	
H-8	THERMOSTATS	33	33	98	30	30	90	29	29	87
H-9	ENTHALPY CONTR.	5.7			5.3			6.1		
H10	REPLACE ROOM AC		27	27		26	26		51	51
H11	REPLACE CENT.AC	210			198			477		
H12	VARY CHW TEMP.	35			33			38		
H13	REHEAT-VAV									
H14	REDUCE VENTIL.							1.4		
H15	EVAP. COOLING									
H16	WATER-CL.CONDEN	61			57			113		
H17	FOG COOLING									
H18	INSULATE DUCTS	54			54			45		
H19	INSULATE PIPES		391			350			331	
H20	2-SPEED FAN MOT	12			11			10.7		
D-1	SUMMER DHW HTR.		14			14				
D-2	FLOW CONTROLS	0.8	0.8	0.8	0.8	0.8	0.8	5.3	5.3	5.3
D-3	INSULATE STORAG	2.2	2.1	1.8	2.2	2.1	1.8	18	18	55
D-4	DHW VENT DAMPER	2.6	2.6	2.6	2.6	2.6	2.6	5.2	5.2	5.2
D-5	DHW HEAT PUMP	9	9	21	9	9	21			
L-1	INCAN.-FLUOR.	10	14	7.8	10	14	7.8	4.2	6.0	33
L-2	HYBRID LAMPS	15	22	12	15	22	12	20	26	15
L-3	TASK LIGHTING							56	20	44
L-4	HI-EFFIC.FLUOR.							30	.12	.23

LABEL	TABLE 8-4 TAMPA (3) MEASURE	CAV/COMP/3	MBW/AIR/3	MBW/H20/3	MBW/DEC/3	MBW/COMP/3	CLAD/AIR/3	CLAD/H20/3	CLAD/DEC/3	CLAD/COMP/
E-1	ROOF/ATTIC INS.	247	228	144	172	228	180	137	172	227
E-2	WALL INSUL.	24	363	277	338	449	316	241	293	391
E-3	STORM WINDOWS	91	54	42	51	68				
E-4	DOUBLE GLAZING	364	165	80	131	174	129	98	120	160
E-5	WEATHERSTRIPPIN	190	59	45	56	74	108	85	113	144
E-6	WINDOW INSUL.	304	249	249	746	249	249	249	746	249
E-7	REFLECT. FILMS	111	88	73	92	111	93	73	92	92
E-8	SHADING DEVICES	61	50	24	46	58	18	38	51	65
E-9	ROOF SPRAYS	7.8	5.9	4.0	4.0	5.9	5.9	4.0	4.0	5.9
H-1	REPLACE BURNER	6.6	153	153		7.7	151	151		7.9
H-2	REPLACE BOILER	9		164		9.5		164		9.4
H-3	VENT DAMPER	2.6	19	13		1.7	19	13		1.7
H-4	STACK HT. RECL.	3.5		66		3.1		68		3.3
H-5	ELEC. HEAT PUMP									
H-6	BOILER TURBUL.	12		470		16		458		15
H-7	MODUL. AOUASTAT			23				24		
H-8	THERMOSTATS	63	28	28	84	61	27	27	81	58
H-9	ENTHALPY CONTR.		5.0				5.2			
H10	REPLACE ROOM AC			47	47			50	50	
H11	REPLACE CENT.AC	477	450			450	467			467
H12	VARY CHW TEMP.		36				37			
H13	REHEAT-VAV	1.0				0.8				0.8
H14	REDUCE VENTIL.		1.2				1.2			
H15	EVAP. COOLING									
H16	WATER-CL. CONDEN	113	107			107	111			111
H17	FOG COOLING									
H18	INSULATE DUCTS	83	71			124	67			118
H19	INSULATE PIPES			555				517		
H20	2-SPEED FAN MOT		12				12			
D-1	SUMMER DHW HTR.									
D-2	FLOW CONTROLS	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3
D-3	INSULATE STORAG	40	18	18	55	40	18	18	55	40
D-4	DHW VENT DAMPER	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2
D-5	DHW HEAT PUMP									
L-1	INCAN.-FLUOR.	42	42	60	33	42	42	60	33	42
L-2	HYBRID LAMPS	20	20	28	15	20	20	28	15	20
L-3	TASK LIGHTING	57	57	80	44	57	57	80	44	57
[illegible]	[illegible]	30	36	42	30	30	30	42	23	30

TABLE 8-4
TAMPA
(4)

LABEL	MEASURE	MBW/AIR/4	MBW/H20/4	MBW/DEC/4	MBW/COMP/4	CLAD/AIR/4	CLAD/H20/4	CLAD/DEC/4	CLAD/COMP/	MBW/AIR/5.
E-1	ROOF/ATTIC.INS.	180	137	172	228	180	137	172	228	180
E-2	WALL INSUL.	363	277	338	449	316	241	293	391	363
E-3	STORM WINDOWS									
E-4	DOUBLE GLAZING	100	77	94	125	129	98	120	160	129
E-5	WEATHERSTRIPPIN	71	55	68	89	186	150	209	258	198
E-6	WINDOW INSUL.	249	249	746	249	249	249	746	249	249
E-7	REFLECT. FILMS	93	73	92	118	93	73	92	118	
E-8	SHADING DEVICES	43	34	46	58	48	38	51	65	
E-9	ROOF SPRAYS	5.9	4.0	4.0	5.9	5.9	4.0	4.0	5.9	5.9
H-1	REPLACE BURNER	107	107		3.6	114	114		3.1	96
H-2	REPLACE BOILER		133		5.4		138		4.9	
H-3	VENT DAMPER	8.3	5.5		0.5	10.3	6.8		0.5	8.8
H-4	STACK HT. RECL.		46		1.2		54		1.2	
H-5	ELEC. HEAT PUMP									
H-6	BOILER TURBUL.		606		9.6		600		8.4	
H-7	MODUL.AOUASTAT		14				17			
H-8	THERMOSTATS	27	27	82	59	26	26	79	57	27
H-9	ENTHALPY CONTR.	1.3				1.4				1.4
H10	REPLACE ROOM AC		61	61			64	64		
H11	REPLACE CENT.AC	480			480	508			508	194
H12	VARY CHW TEMP.	8.8				9.3				10
H13	REHEAT-VAV				0.5				0.5	
H14	REDUCE VENTIL.	0.8				0.9				
H15	EVAP. COOLING									
H16	WATER-CL.CONDEN	96			96	102			102	44
H17	FOG COOLING									
H18	INSULATE DUCTS	85			143	82			138	81
H19	INSULATE PIPES		529				502			
H20	2-SPEED FAN MOT	12				12				11
D-1	SUMMER DHW HTR.									
D-2	FLOW CONTROLS	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1.3
D-3	INSULATE STORAG	19	19	56	56	19	19	56	40	2.6
D-4	DHW VENT DAMPER	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	0.7
D-5	DHW HEAT PUMP									8.6
L-1	INCAN.-FLUOR.	42	60	33	42	42	60	42	42	14
L-2	HYBRID LAMPS	14	21	11	14	14	21	11	14	13
L-3	TASK LIGHTING	70	99	54	70	70	99	54	70	
L-4	HI-EFFIC.FLUOR.	30	42	30	30	30	42	30	30	

A-20

LABEL	TABLE 8-4 TAMPA (5) MEASURE	MBW/H20/5	MBW/DEC/5	CLAD/AIR/5	CLAD/H20/5	CLAD/DEC/5				
E-1	ROOF/ATTIC INS.	137	172	180	137	172				
E-2	WALL INSUL.	277	338	316	241	293				
E-3	STORM WINDOWS									
E-4	DOUBLE GLAZING	98	120	129	98	120				
E-5	WEATHERSTRIPPIN	152	188	198	152	188				
E-6	WINDOW INSUL.	249	754	249	249	745				
E-7	REFLECT. FILMS									
E-8	SHADING DEVICES									
E-9	ROOF SPRAYS	4.0	4.0	5.9	4.0	4.0				
H-1	REPLACE BURNER	96		83	83					
H-2	REPLACE BOILER	98			86					
H-3	VENT DAMPER	5.8		7.5	5.0					
H-4	STACK HT. RECL.	40			35					
H-5	ELEC. HEAT PUMP									
H-6	BOILER TURBUL.	357			315					
H-7	MODUL.AOUASTAT	14			12					
H-8	THERMOSTATS	27	82	26	26	77				
H-9	ENTHALPY CONTR.			1.4						
H10	REPLACE ROOM AC	36	36		36	36				
H11	REPLACE CENT.AC			189						
H12	VARY CHW TEMP.			9.9						
H13	REHEAT-VAV									
H14	REDUCE VENTIL.									
H15	EVAP. COOLING									
H16	WATER-CL.CONDEN			43						
H17	FOG COOLING									
H18	INSULATE DUCTS			74						
H19	INSULATE PIPES	309			275					
H20	2-SPEED FAN MOT			9.3						
D-1	SUMMER DHW HTR.	14			14					
D-2	FLOW CONTROLS	1.3	1.3	1.3	1.3	1.3				
D-3	INSULATE STORAG	2.3	2.0	2.6	2.3	2.0				
D-4	DHW VENT DAMPER	0.7	0.7	0.7	0.7	0.7				
D-5	DHW HEAT PUMP	8.6	17	8.6	8.6	17				
L-1	INCAN.-FLUOR.	19	11	14	19	11				
L-2	HYBRID LAMPS	18	10	13	18	10				
L-3	TASK LIGHTING									

Section K: Fuel Factors Used to Adjust Energy Savings for the Difference in Price between Oil and Electricity

This section presents the methodology used in converting million Btus of savings into savings adjusted for the generally higher price of electricity. The section begins with a memo from Gordon Kramer of Energyworks to Mary Procter explaining the methodology. The section then presents the algorithms used for allocating savings between oil and electricity. The section finally shows actual fuel factors calculated for most retrofits with mixed impacts on both oil and electricity.

July 12, 1982

TO: Mary Procter

FROM: Gordon Kramer

RE: Fuel Cost Adjustment Factors Applied to Cost/Savings (C/S) Ratios for Measures with Mixed Fuel Savings

The attached material is a copy of my original calculations of the C/S ratio fuel adjustment factors. The actual formulas used to calculate the factors on the last sheet begin at the bottom of the 3rd page. Abbreviations in the formulas are defined as follows (appropriate to climate and building/system type):

HDD, CDD = Heating, cooling degree-days
SHE = Seasonal heating efficiency
SCOP = Seasonal cooling system C.O.P.
INL,W = Winter infiltration load (BTU)
INL,S = Summer infiltration load (BTU)
SSHG,W,S = Seasonal solar heat gain, winter, summer
HOH = Heating system operating hours, seasonal
COH = Cooling system operating hours, seasonal
SHL = Total seasonal heating load (BTU)
PHL = Peak heating load (BTU/Hr)
LHS = Length of heating season
LCS = Length of cooling season
DHWSE = Seasonal (yearly) efficiency, DHW system

FUEL FACTORS

Existing C/S figures based on \$7.143/10^6 BTU (Oil @ \$1.00/140 MBTU)

1) All-Electric measures, reduce C/S by $\frac{7.143}{17.58}$

$= \underline{0.4063}$

Yields cost per oil-equivalent BTU, then C/S payback threshholds of 14.3, 50.0, and 114.3 (for 2, 7, 16 yr. payback) will still apply across all measures.

APPLICABILITY

DECENTRALIZED: All measures.

AIR, WATER, COMPLEX SYS: The following all-electric measures

HVAC-9
HVAC-10
HVAC-11
HVAC-12
HVAC-15
E-9

HVAC-25
HVAC-16
HVAC-17
HVAC-24
HVAC-26

2) MIXED EFFECTS (see formulas below)

E-1
E-2
E-3
E-4

E-5
E-7
E-8

HVAC-13
HVAC-14
HVAC-18
HVAC-20

DHW-3
DHW-6

L-1
L-2
L-3
L-4

MEASURES W/MIXED FUEL SAVINGS

E-1,2 FACTOR $= \left(\frac{\text{HDD}}{\text{SHE}} + \frac{\text{CPP}}{\text{SCOP}}\right)$

E-3,4 $\left[\left(\frac{\text{HDD}}{\text{SHE}} + \frac{\text{CDD}}{\text{SCOP}}\right) \times f_1\right] + \left[\frac{\text{INL,W}}{\text{SHE}} + \frac{\text{INL,S}}{\text{SCOP}}\right) \times f_2\right]$

E-3 $\left(\frac{\text{INL,W}}{\text{SHE}} + \frac{\text{INL,S}}{\text{SCOP}}\right)$ INL is a function of HDD or CDD
: E-1 thru E-5 all:: DD

E-7 $\frac{(f_1 \times \text{CDD}) + (F_2 \times \text{SSHG,S})}{\text{SCOP}} + \frac{(F_3 \times \text{HDD}) + (f_4 \times \text{SSHG,W})}{\text{SHE}}$

where $f_3 \quad f_1$ and $f_4 = - f_2$

$\frac{f_1 \times \text{CDD}}{\text{SCOP}} + \frac{f_2 \times \text{SSHG,S}}{\text{SCOP}} + \frac{f_1 \times \text{HDD}}{\text{SHE}} - \frac{f_2 \times \text{SSHG,W}}{\text{SHE}}$

$= \left[f_1 \times \left(\frac{\text{HDD}}{\text{SHE}} + \frac{\text{CDD}}{\text{SCOP}}\right)\right] + \left[f_2 \times \left(\frac{\text{SSHG,S}}{\text{SCOP}} - \frac{\text{SSHG,W}}{\text{SHE}}\right)\right]$

E-8 $\left[\left(\frac{\text{HDD}}{\text{SHE}} + \frac{\text{CDD}}{\text{SCOP}}\right) \times f_1\right] + \left[\left(\frac{\text{SSHG,S}}{\text{SCOP}} - \frac{\text{SSHG,W, PARTIAL}}{\text{SHE}}\right) \times f_2\right]$

All factors above with SCOP in denom.: apply fuel factor

H-3 Separate H&C equations, no constitutive formula

H-14 $\left(\frac{\text{HDD}}{\text{SHE}} \times \frac{\text{CDD}}{\text{SCOP}}\right)$

H-18 $[(f_1 \times \frac{HOH}{SHE}) + (f_2 \times \frac{COH}{SCOP})]$

where HOH function $(\frac{SHL}{PHL})$ similar for COH

H-20 Separate H and electric power components

DHW-3 Applies to residential only:

$$[f_1 - (f_2 \times \frac{LHS}{SHE}) + (\frac{LCS}{SCOP})$$

L-1,2,3,4

$$[f_1 + f_2 (\frac{LCS}{SCOP} - \frac{LHS}{SHE})] \times f_0$$

where $f_1 = 52$, $f_2 = 1/7$ for all L measures.

FACTORING METHODOLOGY

Savings multiplied by $\frac{17.58}{7.143} = \underline{2.461}$ for electrical portion of savings.

- Yields reduced C/S ratio which can be evaluated in terms of oil-equivalent level cutoffs.

$$S' = S_{OIL} + 2.461\ S_{ELEC}$$

$$\frac{S'}{S} = \frac{S_{OIL} + 2.461\ S_{ELEC}}{S_{OIL} + S_{ELEC}} \quad \text{EX: } \frac{(\frac{HDD}{SHE} + 2.461\ \frac{CDD}{SCOP})}{\frac{HDD}{SHE} + \frac{CDD}{SCOP}}$$

C/S ratio is multiplied by inverse of ratio

$$+ \frac{S_{TOTAL}}{S_{OIL} + 2.461\ S_{ELEC}}$$

MEASURES

and H-14
E-1 thru E-5 $\frac{(HDD/SHE + CDD/SCOP)}{(HDD/SHE + 2.461\ CDD/SCOP)}$

All L Measures

$$(52 + ((\frac{LCS}{SCOP} - \frac{LHS}{SHE})/7))/(\overset{(52 \times 2.416)}{\overbrace{128}} + (((2.461 \times \frac{LCS}{SCOP} - \frac{LHS}{SHE})/7))$$

DHW-3 $(\ \underline{\ 1\ } - \underline{.5 \times LHS} + \underline{\quad LCS\quad}\ )$

DHWSE   365 x SHE   365 x SCOP

$$= \frac{1}{365}\left(\frac{365}{DHWSE} - (.5 \times \frac{LHS}{SHE}) + \frac{LCS}{SCOP}\right)$$

Use DHWSE = .497 for Residential

$$\therefore \text{Base factor} = (734 - (.5 \times \frac{LHS}{SHE}) + \frac{LCS}{SCOP})$$

$$\text{Fuel Factor} = (734 - (.5 \times \frac{LHS}{SHE}) + \frac{LCS}{SCOP})$$

$$/(734 - (.5 \times \frac{LHS}{SHE}) + (2.461 \times \frac{LCS}{SCOP}))$$

HVAC-18

AIR $((4.9405 \times \frac{HOH}{SHE}) + (2.5189 \times \frac{COH}{SCOP}))$

HOH
F12, G112

$/((4.9405 \times \frac{HOH}{SHE}) + (6.199 \times \frac{COH}{SCOP}))$

COMP $((1.3994 \times \frac{HOH}{SHE}) + (2.5189 \times \frac{COH}{SCOP}))$

COH
H12, H12

$/((1.3994 \times \frac{HOH}{SHE}) + (6.199 \times \frac{COH}{SCOP}))$

E-7

$$\text{Base Factor} = [.275 \times (\frac{HDD}{SHE} + \frac{CDD}{SCOP})] + [.72 \times (\frac{SSHG}{SCOP} - \frac{SSHE}{SHE})]$$

B18,B18,C18	D18,E18,D18	D67,E67,D67	B67,B67,C67	BUF
B19 C19	D19 D19	H67,I67,H67	F67,F67,G67	STL
B20 C20	D20 D20	D83,E83,D83	B83,B83,C83	MEM
B21 C21	D21 D21	H83,I83,H83	F83,F83,G83	TAM

FUEL COST ADJUSTMENT FACTORS

MULTIPLY $\frac{\text{COST}}{\text{SAVINGS}}$ ratios by these factors:

i.e. C/S × FACTOR = FUEL-ADJUSTED C/S

OR SAVINGS × $\frac{1}{\text{FACTOR}}$ = FUEL-ADJUSTED SAVINGS

MEASURES E1 - E5

A →

B ↓	AIR	WATER	COMP
BUFFALO	.944	.928	.935
ST.LOUIS	.827	.79	.8
MEMPHIS	.781	.74	.726
TAMPA	.46	.448	.457

MEASURE DHW - 3

A →

B ↓	AIR	WATER	COMP.
BUFFALO	.874	.833	.88
ST.LOUIS	.843	.796	.85
MEMPHIS	.837	.789	.847
TAMPA	.812	.761	.813

MEASURE H - 18

A →

B ↓	AIR	COMP.
BUFFALO	.892	.714
ST.LOUIS	.789	.583
MEMPHIS	.728	.537
TAMPA	.655	.482

FUEL FACTOR, 2-SPEED FAN MOTORS (HVAC-20)

	BUFFALO	ST.LOUIS	MEMPHIS	TAMPA
PU 1A	.450025	.446019	.440916	.413504
PU 1B	.451010	.447356	.444745	.413536
PU 2A	.419156	.417742	.414149	.408187
PU 2B	.425189	.418649	.414772	.408327
PU 2C	.426102	.419635	.417203	.408530
PU 3A	.420630	.414589	.412785	.408051
PU 3B	.423110	.420889	.417104	.409732
PU 3C	.421495	.419656	.415962	.409432
PU 4B	.427612	.423544	.415590	.410059
PU 4C	.422102	.418766	.412210	.409196
PU 5B	.437206	.445794	.495970	.408990
PU 5C	.436644	.443782	.503563	.409079

CONVERT REHEAT TO VARIABLE AIR VOLUME (HVAC-13)

	BUFFALO COMPLEX	FUEL FACTOR	ST.LOUIS COMPLEX	FUEL FACTOR	MEMPHIS COMPLEX	FUEL FACTOR	TAMPA COMPLEX	FUEL FACTOR
PU 3A		.884632		.822997		.812534		.681644
PU 3B		.884400		.829769		.820807		.693803
PU 3C		.883573		.828872		.818421		.691766
PU 4B		.879638		.821046		.810792		.680074
PU 4C		.878487		.817216		.808921		.678592

FUEL FACTORS - MEASURES E7 AND E8

	BUFFALO	ST.LOUIS	MEMPHIS	TAMPA
PU 1A	.9428640	.8249571	.7789792	.4591852
PU 1B	.9439020	.8264625	.7805448	.4598709
PU 2A	.9381435	.8170856	.7707713	.4554426
PU 2B	.9379291	.8168270	.7705189	.4553261
PU 2C	.9379598	.8170856	.7699056	.4554426
PU 3A	.9343695	.8114518	.7641955	.4526082
PU 3B	.9344136	.8106782	.7635784	.4518926
PU 3C	.9344136	.8106782	.7635784	.4520081
PU 4B	.8782126	.7177374	.6672797	.4143138
PU 4C	.8787148	.7184949	.6639257	.4156356
PU 5B	.9021086	.7524653	.6816070	.4321532
PU 5C	.9023668	.7544116	.6816070	.4327489

LIGHTING MEASURES

For the four lighting measures which follow, fuel-adjusted savings have been calculated. To obtain cost / savings ratios, divide these savings into the costs which are presented in Section H.

SAVINGS W/FUEL FACTOR HIGH-EFFICIENCY FLUORESCENT LAMPS (L-4)

	BUF AIR	BUF WAT	BUF COM	ST.L AIR	ST.L WAT	ST.L COM	MEM AIR	MEM WAT	MEM COM	TAM AIR	TAM WAT	TAM COM
PU 3A	295.6795	131.2465	135.4803	277.2928	187.5060	164.9798	283.9685	182.9143	165.5209	250.3467	167.3301	216.0208
PU 3B	296.0317	135.1196	135.4803	275.5323	168.8444	164.9798	282.5601	168.4780	165.5209	249.2904	167.3301	216.0208
PU 3C	296.0317	135.1196	135.4803	275.5323	168.8444	164.9798	282.5601	168.4780	165.5209	249.2904	167.3301	216.0208
PU 4B	1780.885	835.1676	814.0623	1655.594	1014.538	991.3165	1693.591	963.6748	994.5675	1497.914	1005.438	1298.007
PU 4C	1783.001	858.4403	814.0623	1657.710	1025.116	991.3165	1689.359	910.7824	994.5675	1497.914	1005.438	1298.007

SAVINGS W/FUEL FACTOR CONVERT INCANDESCENT TO FLUORESCENT (L-1)

	BUF AIR	BUF WAT	BUF COM	ST.L AIR	ST.L WAT	ST.L COM	MEM AIR	MEM WAT	MEM COM	TAM AIR	TAM WAT	TAM COM
PU 1A	38.0661	16.1561	17.66412	35.298	24.2235	21.59219	36.759	25.4384	21.68159	27.7469	21.5944	28.43830
PU 1B	37.82	13.7951	17.66412	35.0519	21.2703	21.59219	36.5129	20.7625	21.68159	27.7469	21.5944	28.43830
PU 2A	588.371	220.8762	270.1556	548.541	348.7078	329.4799	565.612	375.8689	330.4959	434.661	332.2834	430.4709
PU 2B	583.449	149.5384	270.1556	546.08	328.5276	329.4799	563.151	356.1809	330.4959	434.661	332.2834	430.4709
PU 2C	583.449	159.3824	270.1556	548.541	348.7078	329.4799	558.229	308.6836	330.4959	434.661	332.2834	430.4709
PU 3A	3795.227	1274.379	1739.718	3559.942	2408.194	2118.964	3646.985	2348.808	2123.810	2826.066	2149.291	2772.472
PU 3B	3800.149	1327.013	1739.718	3537.793	2167.016	2118.964	3627.297	2163.002	2123.810	2813.761	2149.291	2772.472
PU 3C	3800.149	1327.013	1739.718	3537.793	2167.016	2118.964	3627.297	2163.002	2123.810	2813.761	2149.291	2772.472
PU 4B	23024.91	8348.564	10529.51	21403.25	13117.06	12820.47	21898.36	12462.88	12855.71	17027.91	13006.64	16780.52
PU 4C	23021.99	8648.806	10528.99	21427.86	13252.42	12818.81	21841.75	11776.26	12853.95	17025.45	13006.64	16776.89
PU 5B	4577.159	1659.670	2093.527	4226.909	2314.712	2547.632	4206.434	874.24	2555.083	3384.465	2584.64	3335.196
PU 5C	4579.62	1720.934	2093.527	4241.675	2437.762	2547.632	4203.973	854.552	2555.083	3384.465	2584.64	3335.196

SAVINGS W/FUEL FACTOR HYBRID LAMPS (L-2)

	BUF AIR	BUF WAT	BUF COM	ST.L AIR	ST.L WAT	ST.L COM	MEM AIR	MEM WAT	MEM COM	TAM AIR	TAM WAT	TAM COM
PU 1A	17.8334	9.2199	8.281181	16.6185	11.4504	10.17033	17.0568	11.84064	10.19418	12.91202	10.00435	13.35589
PU 1B	17.5873	8.2355	8.281181	16.6185	10.2199	10.17033	16.8107	9.565068	10.19418	12.91202	10.00435	13.35589
PU 2A	370.1255	177.9214	169.4136	345.1048	219.3477	207.2864	354.6091	236.0554	207.5946	274.3626	209.3244	270.4190
PU 2B	366.1879	134.8539	169.4136	343.6282	206.5505	207.2864	353.3786	223.7509	207.5946	274.3626	209.3244	270.4190
PU 2C	366.434	141.0064	169.4136	345.1048	219.3477	207.2864	350.6715	193.8685	207.5946	274.3626	209.3244	270.4190
PU 3A	3640.425	1615.760	1667.780	3413.367	2308.378	2031.115	3496.027	2251.666	2037.719	2709.962	2060.021	2659.028
PU 3B	3642.886	1663.504	1667.780	23079.22	2079.505	2031.115	3478.8	2074.016	2037.719	2696.964	2060.021	2659.028
PU 3C	3642.886	1663.504	1667.780	3391.218	2079.505	2031.115	3478.8	2074.016	2037.719	2696.964	2060.021	2659.028
PU 4B	22025.50	10330.83	10069.82	20477.73	12548.39	12261.06	20946.08	11919.79	12300.10	16280.71	12434.55	16052.93
PU 4C	22050.11	10618.77	10069.46	20499.88	12678.83	12259.95	20891.94	11265.14	12298.92	16278.28	12432.84	16050.50
PU 5B	3106.962	1456.862	1419.815	2868.592	1569.184	1728.668	2854.429	593.1312	1735.026	2295.230	1752.911	2263.781
PU 5C	3106.962	1497.222	1419.815	2878.436	1655.319	1728.668	2854.429	581.0649	1735.026	2294.646	1752.495	2263.781

SAVINGS W/FUEL FACTOR TASK LIGHTING (L-3)

	BUF AIR	BUF WAT	BUF COM	ST.L AIR	ST.L WAT	ST.L COM	MEM AIR	MEM WAT	MEM COM	TAM AIR	TAM WAT	TAM COM
PU 3A	752.9942	334.2396	345.0218	706.1694	477.5133	420.1470	723.1701	465.8199	421.5248	560.6358	426.1322	550.1307
PU 3B	753.8909	344.1032	345.0218	701.6860	429.9887	420.1470	719.5833	429.0555	421.5248	557.9457	426.1322	550.1307
PU 3C	753.8909	344.1032	345.0218	701.6860	429.9887	420.1470	719.5833	429.0555	421.5248	557.9457	426.1322	550.1307
PU 4B	2616.559	452.5776	629.0208	2610.791	1143.931	1315.533	2611.117	940.9299	1372.133	2518.328	1806.683	2506.569
PU 4C	2621.400	505.8299	629.0208	2615.632	1168.136	1315.533	2601.435	819.9019	1372.133	2518.328	1806.683	2506.569

Section L: Algorithms for Retrofit Measures and Sources Used for Algorithms and Cost Data

This section presents the algorithms used for each of the retrofit measures for which calculations were done. Following the individual descriptions of solar retrofit measures (S1-7) there is a general description of the methodology used for the solar calculations. At the end of the section, we have reproduced, for convenience, the list of data sources used for cost and savings estimates which was printed as Appendix D in the full report.

PARAMETERS USED IN SAVINGS ALGORITHMS

U,R = Existing U-Value of roof, Btu/Hr-Ft^2-$^\circ$F

A,R = Area of roof, ft^2

HDD = Heating degree days, base 60

CDD = Cooling degree days, base 60

DD,NT = Degree days, night

SHE = Seasonal heating efficiency

SCOP = Seasonal cooling efficiency (coefficient of performance)

U,W = Existing wall U-Value

A,W = Wall area

U,WI = Window U-Value

A,WI = Window area

INL,W = Existing winter season infiltration load, Btu

INL,S = Existing summer season infiltration load, Btu

CL,W = Window crack length, ft

CL,D = Door crack length, ft

HDD,DAY = Heating degree days occurring during daylight hours

SSHG,W = Seasonal solar heat gain without films, winter

SSHG,S = Same, summer

WSG, SO = Winter solar gain on south side, Btu/ft^2

S,E3 = Savings from measure E-3, storm windows

LHS = Length of heating season (days)

LCS = Length of cooling season (days)

% SUN = Average percentage of possible sunshine during the cooling season

HEU = Existing building heating energy use

SHE = Seasonal heating efficiency of existing system

SHERH = Seasonal efficiency of similar boiler with retention-head burner

HPUT = Heating percentage on-time, used to determine SHE and SHERH

SHENEW = Seasonal efficiency of new equipment

RESHE = Seasonal efficiency terminal reheat system (winter and summer)

REHEU = Summer reheat energy use

SHESHR = Seasonal heating efficiency, existing heating plant with stack heat reclaimer

HPSCOP = Seasonal C.O.P. of heat pump, a function of climate

HR, temp. range = Number of hours that the temperature is within the given range (for a modulating aquastat) during the course of an average heating season, a function of climate zone. Percent of energy savings varies with temperature.

TSCFM = Total system air supply, cu. ft./minute (CFM)

VCFM = Ventilation air volume of existing system

OCC:HR = Weekly hours of cooling system operation

K = Seasonal free cooling potential of outside air, a function of climate zone

SCL = Seasonal demand on cooling system, 10^6 Btu

CL,AV = Average instantaneous cooling load occurring during the season, Btu/hr

PCL = Peak cooling load upon which the system is sized, Btu/hr

S.M.A. = Savings from modulating aquastat measure, HVAC-7

OP.HR = Weekly system operating hrs

RESHL,W = Seasonal heating load for reheat system, winter

CPEVAP = Seasonal cooling potential from evaporative cooling, a function of wet-bulb temperature occurrences below 65°F during the cooling season. Varies from 16,527 Btu/CFM/yr for Memphis to 25,980 Btu/CFM/yr for Buffalo

CCSS = Condenser coil spray savings, a function of relative dry-bulb and wet-bulb temperatures over the course of a cooling season

HOH = Heating system on-hours, seasonal

COH = Cooling system on-hours

PLR = Pipe loss reduction factor, a function of pipe length and size, PLR = 6320 Btu/hr for PU 1, 38105 Btu/hr for PU 2, 3, and 155370 Btu/hr for PU 4, 5

HP = Horsepower of original fan motor, sized to peak cooling load

S;H-7 = Savings from measure HVAC-7, modulating aquastat

SHERO = Seasonal efficiency of heating plant after reducing orifice to match output more closely to peak load

SHE,SF = Seasonal efficiency of solid fuel boiler

HV,SF = Heating value of solid fuel, Btu/lb. of Btu/cord

C,SF = Cost of solid fuel, dollars per lb. or per cord

CHR,70+ = Hours in cooling season where outdoor temperature is above 70°F, a function of climate

CST = Capacity of cooling system, tons

OPHR = Operating hours of bypass system, a function of climate

GAL/WK = Weekly hot water use, gallons

T,USE = Domestic hot water supply temperature

CS,DHW,E = Seasonal efficiency of main boiler when used to generate DHW

DHWSE = Seasonal efficiency of separate DHW heater

HLR = Annual tank heat loss reduction

DHWSEVD = DHW seasonal efficiency with vent damper

COPHR = Improved COP of cooling system due to reduction of condensing temperature by reclaim system

EHR = Heat transfer efficiency of reclaim system

EDHW = Steady-state efficiency of existing DHW system

KW,RM,I = Existing installed lighting capacity in rooms, incandescent

KW,RM,F =Capacity of fluorescent lighting required to produce same illumination

KW,COR,I
KW,COR,F = Same as above for corridors

EQ.HR,RM; EQ.HR,COR =
Equivalent weekly hrs of full lighting operation (i.e., multiplying total installed lighting capacity by EQ.HR. yields weekly lighting energy use)

KWR = Kilowatt hour reduction factor = 17.8 for PU 3, = 96.1 for PU 4

% AREA = % of office where light-shelves are effective

USEHRS = Hours/week where daylighting is effective, averaged over the year

E-1 DESCRIPTION ROOF/ATTIC INSULATION

Add R-30 insulation to attic (P/U 1) or flat roof.

$$\begin{aligned}\text{SAVINGS} = {} & ((U,R - (1/((1/U,R) + 30))) \times A,R \times 24) \\ & \times (HHD/SHE + CDD/SCOP)\end{aligned}$$

E-2 DESCRIPTION WALL INSULATION

On cavity walls (3 1/2" cavity), blow in fiberglass insulation or equivalent; on masonry bearing and clad walls, install 2" of rigid polystyrene on exterior, plus a finish layer of masonry compound. R-13 added.

$$\begin{aligned}\text{SAVINGS} = {} & ((U,W - (1/((1/U,W) + 13))) \times A,W \times 24) \\ & \times (HDD/SHE + CDD/SCOP)\end{aligned}$$

E-3 DESCRIPTION STORM WINDOWS

Install aluminum storm windows on buildings with double-hung windows.

$$\begin{aligned}\text{SAVINGS} + {} & [((U,WI - (1/((1/U,WI) + 1.12))) \times A,WI \times 24 \times 10-6 \\ & \times (HDD/SHE + CDD/SCOP)] \\ & + [(.377 \times (INL,W/SHE + INL,S/SCOP)]\end{aligned}$$

E-4 DESCRIPTION REPLACEMENT DOUBLE GLAZING

Buildings with double-hung windows (see E-3): Install new double-glazed windows.
All other types: Install second pane of glass on existing windows.

Building types 2C,3C,4C,5B,5C:

$$\begin{aligned}\text{SAVINGS} = {} & [((U,WI - (1/((1/U,W) + 1.12))) \times A,WI \times 24 \times 10-6 \\ & \times (HDD/SHE + CDD/SCOP)]\end{aligned}$$

Building types 1A,1B,2A,2B,3A,3B,4B:
SAVINGS as above, PLUS: $(.39 \times (INL,W/SHE + INL,S/SCOP))$

E-5 DESCRIPTION WINDOW AND DOOR WEATHERSTRIPPING

For P/U 1, install rubber or plastic gasket weatherstripping on all windows and doors.
For all other types, install spring bronze weatherstripping

$$\begin{aligned}\text{SAVINGS} &= (((F1 \times CL,W) + (F2 \times CL,D))/(CL,W + CL,D)) \\ &\quad \times (INL,W/SHE + INL,S/SCOP)\end{aligned}$$

E-6 DESCRIPTION WINDOW INSULATION

Install "window quilt" or equivalent movable insulation system on all windows. Method assumes insulation is in place on an average of 75% of windows at one time, 8 hours/day. R-3 added.

$$\begin{aligned}\text{SAVINGS} &= [(U,W - (1/((1/U,W) + 3))] \times A,WI \times 24 \times 10^{-6} \\ &\quad \times ((HDD - HDD,DAY)/SHE) \times .75\end{aligned}$$

E-7 DESCRIPTION REFLECTIVE FILMS

Install reflective window films, reducing average solar transmittance by 72%, reducing effective U-value by about 29%.

$$\begin{aligned}\text{SAVINGS} &= [((.30 \times A,WI \times CDD \times 24) + (.72 \times SSHG,S))/SCOP] \\ &\quad + [((.37 \times A,WI \times HDD \times 24) - (.72 \times SSHE,W))/SHE]\end{aligned}$$

E-8 DESCRIPTION SHADING DEVICE

Install exterior-mounted fiberglass-screen shading devices ("Solarscreen" or equivalent).

$$\begin{aligned}\text{SAVINGS} &= (S,E3 \times .85) \\ &\quad + [.65 \times ((SSHG,S/SCOP) - ((SSHG,W \\ &\quad - (WSG,SO \times (A,W1/4)))/SHE))] \times 10^{-6}\end{aligned}$$

E-9 DESCRIPTION ROOF SPRAYING

Install a roof spray system on flat roof buildings to reduce the roof surface temperature on sunny days, thus reducing the cooling load.

$$\text{SAVINGS} = (14.3 \times U,R \times A,R \times 10 \times LCS \times \%\ SUN \times 10^{-6})/SCOP$$

HVAC-1 DESCRIPTION REPLACE BURNER & CONTROLS

Replace existing oil-fired burner with a new retention-head type burner, plus appropriate controls.

SAVINGS = (1 - (SHE/SHERH)) x HEU

HVAC-2 DESCRIPTION REPLACE BOILER/FURNACE

Replace existing boiler plant with a new wet-base, 2-pass horizontal fire tube steel boiler with induced draft burner.

SAVINGS = (1 - (SHE/SHENEW)) x HEU

HVAC-3 DESCRIPTION INSTALL VENT DAMPER ON BOILER/FURNACE

Install mechanically-actuated automatic vent damper on existing heating plant.

AIR AND WATER SYSTEMS: SAVINGS = (1 - (SHE/SHEVD)) x HEU

COMPLEX SYSTEMS: SAVINGS = ((1 - (RESHE,W/SHEVD)) x REHEU,W)
+ ((1 - (RESHE,S/SHEVD)) x REHEU,S)

HVAC-4 DESCRIPTION INSTALL STACK HEAT RECLAIMER

Install device utilizing stack heat to preheat incoming boiler water.

WATER SYSTEMS: SAVINGS = (1 - (SHE/SHESHR)) x HEU

COMPLEX SYSTEMS: using boiler as heat source.
SAVINGS = ((1 - (RESHE,W/SHESHR)) x REHEU,W)
+ ((1 - (RESHE,S/SHESHR)) x REHEU,S)

HVAC-5 DESCRIPTION REPLACE ELECTRIC RESISTANCE WITH HEAT PUMP

Install a split-system air-to-air heat pump as the primary heating source. Electric resistance heating retained as a backup source.

SAVINGS = ((1 - 1/HPSCOP)) x HEU) - (.1765 x CEU)

HVAC-6 DESCRIPTION INSTALL BOILER TURBULATORS

Install turbulators in fire-tubes of existing boiler to increase heat transfer efficiency and reduce stock losses.

SAVINGS = .05 x HEU

HVAC-7 DESCRIPTION INSTALL MODULATING AQUASTAT

Install a water temperature control system to automatically adjust boiler water output temperature in response to outdoor temperature, thus avoiding overheating and reducing boiler jacket and pipe losses.

SAVINGS = (HEU/HR,TOTAL) x ((HR,55-59 x .25) + (HR,45-54 x .238)
+ (HR,35-44 x .21) + (HR,25-34 x .178) + (HR,15-24 x .134)
+ (HR,5-14 x .091) + (HR,-5-5 x .053) + (HR,-15-(-6) x .021))

HVAC-8 DESCRIPTION INSTALL SETBACK THERMOSTATS

Replace existing room or zone thermostats with new timer-actuated units, set to reduce overnight or unoccupied-zone temperatures.

SAVINGS = (BLDG.UA/SHE) x 24 x (DD,60 - (DD,DAY,60+DD,NT,55))

HVAC-9 DESCRIPTION INSTALL ENTHALPY CONTROL/DRY BULB ECONOMIZER

Install controls to shut down mechanical cooling system and open outside air dampers for free cooling when weather conditions are appropriate.

SAVINGS = (TSCFM-VCFM) x K x (OCC.HR/50) x .00093

HVAC-10 DESCRIPTION REPLACE ROOM AC UNITS

Replace existing window or wall-mounted room air-conditioners with new high-efficiency models.

SAVINGS = SCL x ((1/SCOP) - (1/SCOP, NEW))

HVAC-11 DESCRIPTION **REPLACE CENTRAL AC**

Replace existing DX or chilled water central air conditioning system with new high-efficiency equipment.

SAVINGS = SCL x ((1/SCOP) - (1/SCOP,NEW))

HVAC-12 DESCRIPTION **VARY CHILLED WATER TEMPERATURE WITH LOAD**

Install controls and valving to modulate chilled water temperature according to cooling load requirements (outdoor temperature).

SAVINGS = (SCL/SCOP)x(1-(1/1+(F x (1-(CL,AV/PCL)))))
where F = .1674 for reciprocating chillers,
.5672 for centrifugal, and
CL,AV = (BLDG.UA x (78-T,AV)) + (SSHG/TOTAL COOLING HOURS) + PEAK INTERNAL HT. GAIN + ((PVL+PINL) x (dT,AV/dT,MAX)

T,AV = Average outdoor T, cooling season; SSHG = Seasonal solar heat gain;
PVL = Peak ventilation load, BTUH; PINL = Peak infiltration load, BTUH.

HVAC-13 DESCRIPTION **CONVERT TERMINAL REHEAT SYSTEM TO VARIABLE AIR VOLUME (VAV)**

Remove existing heat terminal units and controls; replace with VAV boxes and appropriate controls; adjust total air volume and temperature.

HEATING ENERGY SAVINGS = S,M.A. + ((RESHL/RESHE,W)-(SHL/SHE)) + REHEU,S
COOLING ENERGY SAVINGS = 1.234 x TSCFM x OP.HR. x LCS

HVAC-14 DESCRIPTION **REDUCE VENTILATION VOLUME**

Install low-leakage dampers at outside air intake; reduce ventilation air volume to minimum during occupied hours, shut off during unoccupied hours.

SAVINGS = .154 x ((HDD/SHE) + (CDD/SCOP))
x ((.333 x VCFM x OCC.HR) + (.09 x TSCFM x (168-OCC.HR)))

HVAC-15 DESCRIPTION EVAPORATIVE COOLING SYSTEM

Install an evaporative cooling system to function as supplementary cooling source, using evaporatively cooled outside air, when outdoor conditions are appropriate; existing cooling system retained as primary source.

$$\text{SAVINGS} = \text{CPEVAP} \times \text{TSCFM} \times (\text{OP.HR}/168)$$

HVAC-16 DESCRIPTION REPLACE AIR-COOLED CONDENSER WITH WATER-COOLED

Install a water-cooled condensing system to replace air-cooled system. A system to spray water on air-cooled condensing coils is applicable if it can produce a reduction in condensing temperature comparable to a cooling tower.

$$\text{SAVINGS} = \text{SCL} \times (1/\text{SCOP}) \times (1 - (1/(1 + \text{CCSS})))$$

	CCSS			
	BUF.	ST.L	MEM	TAM.
Reciprocating Machines	.166	.175	.162	.153
Centrifugal	.048	.052	.044	.042

HVAC-17 DESCRIPTION FOG COOLING (EVAPORATOR COIL SPRAY)

Install system to inject a spray of cold water into the air stream leaving the evaporator (cooling) coil, lowering the dry-bulb temperature of the air along a constant wet-bulb line.

$$\text{SAVINGS} = 1.543 \times \text{TSCFM} \times \text{OP.HR.} \times \text{LCS}$$

HVAC-18 DESCRIPTION INSULATE DUCTS

Install 1 1/2" to 2" blanket insulation on all supply ductwork.

$$\text{SAVINGS} = \text{TSCFM} \times ((\text{F} \times \text{HOH}/\text{SHE}) + (2.5189 \times \text{COH}/\text{SCOP}))$$

where $F = 4.9405$ for air systems
$= 1.3994$ for reheat (complex) systems.

The difference in factors is due to the fact that winter primary air temperatures are lower in a reheat system, since air temperature is boosted to actual supply conditions at the point of distribution, reducing duct heat losses.

HVAC-19 DESCRIPTION INSULATE PIPES

Add 1 1/2" to 2" insulation to supply hot water pipes.

SAVINGS = .65 x PLR x HOH

HVAC-20 DESCRIPTION TWO-SPEED FAN MOTORS

Install a 2-speed motor on the central air-handling system to match air supply more closely to load.

LOAD MATCHING SAVINGS = 0.5 x S,H7 [BTU]

FAN POWER SAVINGS = 1780 x HP x HPOT x LHS x 24 x 10^{-6} [BTU]

HVAC-21 DESCRIPTION INSTALL ADJUSTABLE RADIATOR VENTS

Install adjustable air vents on radiators in steam systems, to balance heating system output and avoid overheating.

SAVINGS = F x BLDG.UA. x LHS x 24

This measure is not quantified here due to the difficulty in predicting both dT and F, the degree of overheating and the overheated surface fraction, for any kind of representative building model. The base building models assume that existing control are adequate to maintain uniform building temperature.

HVAC-22 DESCRIPTION REDUCE NOZZLE/ORIFICE SIZE ON FURNACE/BOILER

Install smaller burner orifice or nozzle on boiler or furnace to reduce firing rate of oversized equipment, thus reducing cycling and improving seasonal efficiency of heating plant.

SAVINGS = SHL((1/SHE) - (1/SHERO))

This measure is not quantified because (a) The base case assumption, that the heating plant is considerably oversized, is different from that used for the base building models; (b) Variability in actual base cases and levels of improvement too large to allow meaningful and representative results.

HVAC-23 DESCRIPTION INSTALL MULTIFUEL/SOLID FUEL BOILER/FURNACE

Take advantage of locally available solid fuel sources (wood and coal) to reduce heating costs, versus cost of heating with oil or gas only.

SAVINGS = SHL(($1.00/SHE x 140000)) - (C,SF/(SHE,SFxHV,SF)))

This measure is not quantified because (a) It is primarily a cost-saving measure rather than an energy-saving; (b) Considerable variability in efficiency of equipment, and cost, heating value, and availability of solid fuel.

HVAC-24 DESCRIPTION INSTALL HOUSE FAN(S)

Install exhaust fan in attic or other appropriate location to substitute for mechanical cooling when weather conditions are appropriate.

SAVINGS = USEHRS x (((SCL x F,USE)/(SCOP x LCS x 24)) - HP,FAN)

This measure is not quantified because (a) Limited applicability; (b) Use factor highly dependent on individual behavior, use factor difficult to predict; (c) Efficacy of fan and capability to substitute for all mechanical cooling in house depends on installation.

HVAC-25 DESCRIPTION CONDENSER COIL SPRAY

Install a system to spray water on the coils of air-cooled condenser, lowering the condensing temperature and thus raising the coefficient of performance (COP) of the system.

SAVINGS = (SCL/SCOP) x (1/1.053) x (CHR,70+/COH)

This measure is not quantified because (a) It is very similar in approach to HVAC-16; (b) Data on spray system equipment performance and cost was not readily obtainable.

HVAC-26 DESCRIPTION CHILLER BYPASS SYSTEM

Where a chilled water cooling system is in use, install a system to circulate cooling water directly through the cooling tower, bypassing the chiller, when outdoor temperatures are low enough.

SAVINGS = OPHR x CST x 12000/COP

In attempting to model this measure, it was found that it would operate only at temperatures below those normally occuring during the cooling season. Such systems are used mainly to condition interior zones that require cooling outside of the normal cooling season. Since the building models do not incorporate zone modeling, it was not possible to quantify this measure.

DHW-1 DESCRIPTION INSTALL SUMMER DHW BOILER

Install separate domestic hot water system for summer use.

SAVINGS = (1.191 x GAL/WK x LCS x (T,USE - 60))
x ((1/CS,DHW,E) - (1/DHWSE))

DHW-2 DESCRIPTION INSTALL FLOW CONTROL DEVICES

Install flow-reducing faucet adapters and shower-heads on all fixtures.

COMMERCIAL TYPES 3,4: SAVINGS = 26.81 x GAL/WK x LHTS/DHWSE

RESIDENTIAL TYPES 1,2,5: SAVINGS = 22,855 x GAL/WKC/DHWSE

DHW-3 DESCRIPTION INSULATE DHW STORAGE TANK

Install 1 1/2" to 2" boiler-type insulation on separate DHW storage tank (PU 2-5); Install 1" to 1 1/2" blanket insulation over DHW heater, PU 1.

RESIDENTIAL PU types 1,2,5:
SAVINGS = HLR x ((1/DHWSE) - (.5xLHS/(365xSHE)) + (LCS/(365xSCOP)))

COMMERCIAL TYPES 3,4:
SAVINGS = HLR x (0.6/SHE)
Assumes DHW generated by tankless coil in boiler

DHW-4 DESCRIPTION INSTALL VENT DAMPER ON DHW HEATER

Install an electrically-actuated automatic vent damper on DHW heater.

SAVINGS = (1-(DHWSE/DHWSEVD)) x (GAL/WK x 52 x 8.34 x (T,USE-55))/DHWSE

DHW-5 DESCRIPTION HEAT PUMP FOR DOMESTIC HOT WATER

Install an electric air-to-water heat pump to replace existing equipment. While heat pump retrofit packages may be available for electric resistance water heaters, it is assumed here that a complete new system is installed.

SAVINGS = .0369 x GAL x ((1/DHWSE) - .357) x 10-6

DHW-6 DESCRIPTION REFRIGERATION HEAT RECLAIM FOR DHW

Install a special heat exchanger on the condenser side of the cooling system to extract waste heat for domestic hot water.

SAVINGS = (((CSTx(1+1/COP)xEHR)/EDHW)+(CST(1/COP - 1/COPHR)))

This measure was not quantified because (a) It was difficult to obtain data on the performance and cost of heat reclaim systems; (b) Total system cost is highly variable depending on the difficulty of intergrating piping between the DHW and cooling systems.

L-1 DESCRIPTION REPLACE INCANDESCENT LIGHTS WITH FLUORESCENT

Remove existing incandescent fixtures, replace with recessed fluorescent fixtures providing same level of illumination.

PU 2,5: SAVINGS = ((KW,COR,I-(1.16xKW,COR,F)) x EQ.HR,COR) x 3413
x (52 + (((LCS/SCOP) - (LHS/SHE))/7))

PU 3,4: SAVINGS = (((KW,RM,I - (1.16xKW,RM,F)) x EQ.HR,RM)
+ ((KW,COR,I - (1.16xKW,COR,F)) x EQ.HR,COR))
x 3413 x (52 + (((LCS/SCOP)-(LHS/SHE))/7))

L-2 DESCRIPTION INSTALL FLUORESCENT HYBRID LAMPS

Install fluorescent hybrid lamps in existing incandescent fixtures. Method assumes use in all fixtures for commercial buildings, in all corridor fixtures and 70% of room buildings for residential.

$$
\begin{aligned}
\text{SAVINGS} = {} & (3413 \times .67 \times [(\text{KW,RM,I} \times \text{EQ.HR,RM} \times \text{F1}) \\
& + (\text{KW,COR,I} \times \text{EQ.HR.,COR} \times \text{F2})] \\
& \times [52 + (((\text{LCS/SCOP}) - (\text{LHS/SHE}))/7)]
\end{aligned}
$$

where $\text{F1} = 1$, $\text{F2} = 1$ for P/U 3,4
$\text{F1} = .70$, $\text{F2} = 1$ for P/U 2,5
$\text{F1} = .70$, $\text{F2} = 0$ for P/U 1

L-3 DESCRIPTION USE LOW WATTAGE TASK LIGHTING

Install task lighting (40 W fluorescent) at work stations in commercial buildings; reduce overall lighting level to 20 foot candles.

$$
\begin{aligned}
\text{SAVINGS} = {} & \text{KWR} \times \text{EQ.HR,RM} \times 3413 \\
& \times [52 + (((\text{LCS/SCOP} - (\text{LHS/SHE}))/7)]
\end{aligned}
$$

L-4 DESCRIPTION USE HIGH-EFFICIENCY FLUORESCENT LAMPS

Replace standard 40-W fluorescent lamps with high-efficiency lamps, providing a 21% reduction in wattage with equivalent illumination level.

$$
\begin{aligned}
\text{SAVINGS} = {} & .21 \times 3413 \times [(\text{KW,RW,F} \times \text{EQ.HR,RM}) \\
& + (\text{KW,COR,F} \times \text{EQ.HR,COR})] \\
& \times [52 + (((\text{LCS/SCOP} - (\text{LHG/SHE}))/7]
\end{aligned}
$$

L-5 DESCRIPTION MAXIMIZE USE OF DAYLIGHTING

Install "light shelves", reflective ceiling panels, etc., to maximize effectiveness of daylighting to substitute for electric lighting in commercial applications.

$$
\begin{aligned}
\text{SAVINGS} = {} & \text{KW,RM,I} \times \text{USEHRS} \times \text{\%AREA} \times 3413 \\
& \times (52 + (((\text{LCS/SCOP}) - (\text{LHS/SHE}))/7)
\end{aligned}
$$

This measure is not quantified because (a) Exact specifications for measure cannot be adequately defined; (b) Effectiveness is highly site-specific (a factor of external shading and reflection, etc.); (c) The need for additional control systems not sufficiently defined.

R-1 DESCRIPTION INSTALL SOLAR DOMESTIC HOT WATER

See F-Chart Description, end of this section.

R-2 DESCRIPTION COMBINED ACTIVE SOLAR SPACE HEATING AND DOMESTIC HOT WATER

See F-Chart Description, end of this section.

R-3 DESCRIPTION ADD SUNSPACE

See SLR method description

R-4 DESCRIPTION ADD TROMBE WALL

Glazing is added to South masonry wall to trap solar energy, providing a fraction of the space heating load.

See SLR method description, end of this section.

R-5 DESCRIPTION ADD THERMOSIPHONING AIR PANEL

Glazing is added to non-masonry South wall to trap solar energy, providing a fraction of the space heating load.

See SLR method description, end of this section.

R-6 DESCRIPTION ADD DIRECT GAIN, WITHOUT STORAGE

Glazing is added to non-masonry South wall to trap solar energy, providing a fraction of the space heating load.

See SLR method description

R-7 DESCRIPTION ADD DIRECT GAIN, WITH STORAGE

Glazing is added to non-masonry South wall to trap solar energy; water-wall storage is provided.

See SLR method description, end of this section.

Appendix D

Sources for Cost Estimates and Formulas for Estimating Savings

This appendix shows for each retrofit, the sources used by Energyworks in estimating the costs and savings for that retrofit.

Sources for Costs and Savings Calculations

Envelope retrofits	***Retrofit costs***	***Retrofit savings****
E1. Roof insulation	R. S. Means, *Building Construction Cost Data*, 1980	Carrier *System Design Manual*—Load estimating (ref. 8)
E2. Wall insulation	Same source as E1	Same source as E1
E3. Storm windows	Same source as E1	Same source as E1
E4. Double glazing	Same source as E1	Same source as E1
E5. Weatherstripping	Zero Weatherstripping Co., Bronx, N.Y.	Same source as E1
E6. Window insulation	Appropriate Technology Corp., Brattleboro, Vt. (*Window Quilt*)	Same source as E1 and manufacturers' information
E7. Reflective films	3M Energy Control Products Division, St. Paul, Minn.	Manufacturers' information
E8. Shading devices	Literature from several different products	Same source as E1
E9. Roof sprays	R. S. Means, *Building Construction Data*, sprinkler costs	Same source as E1
HVAC retrofits		
H1. Replace burner	ABC Sunray Corp., Plainview, N.J.	Brookhaven, *Efficiency of Residential Oil-Fired Boilers* (ref. 7)
H2. Replace boiler	Hydrotherm, Inc., Northvale, N.J.	Same source as H1
H3. Vent damper	Flair Manufacturing Corp., Hauppage, N.Y.	Same source as H1
H4. Stack heat reclaimer	Condensing Heat Exchanger Corp., Latham, N.Y.	Same source as H1 plus Bookhaven reports on boiler stack economizers (refs. 9 and 10)
H5. Heat pumps	R. S. Means, *Mechanical and Electrical Cost Data*, 1980	Residential Conservation Service, *Model Audit Manual* (ref. 18)
H6. Boiler turbolators	Fuel Efficiency, Inc. (*Brock Turbolator*) Newark, N.J.	Same source as H1
H7. Modulating aquastat	American Stabilis, Inc. (*Enertrol*) Lewiston, Maine	Hydronics Institute—*Controls for Hydronic Systems* (ref. 14)
H8. Setback thermostats	R. S. Means, *Mechanical Data*	Carrier, *Systems Design Manual* (ref. 8)
H9. Economizer	Honeywell enthalpy control package	Honeywell, *Energy Conservation With Comfort* (source for algorithm)
H10. Room air-conditioners	R. S. Means, *Mechanical Data*	RCS, *Manual* (ref. 18)
H11. Central air-conditioners	R. S. Means, *Mechanical Data*	RCS, *Manual* (ref. 18)
H12. Vary chilled water	Controlled Energy Systems Co., Seattle, Wash.	FEA, *ECM-2* (ref. 12)
H13. Reheat to VAV	R. S. Means, *Mechanical Data*	Honeywell (ref. 13), Hydronics Institute (ref. 14)
H14. Reduce ventilation	Honeywell, Minneapolis, Minn. (*Tradeline*, low leakage damper)	Weather service climate data
H15. Evaporative cooling	R. S. Means	ASHRAE Handbook 1976 (ref. 5)
H16. Water-cooled condenser	R. S. Means	FEA, *ECM-2* (ref. 12)
H17. Fog cooling	Carrier Corp. (*Rota Spray*) sprayed coil system	ASHRAE Handbook 1976, 1977 (refs. 4 and 5)
H18. Insulate ducts	R. S. Means	FEA, *ECM-2* (ref. 12)

HVAC retrofits	***Retrofit costs***	***Retrofit savings****
H19. Insulate pipes	R. S. Means	FEA, *ECM-2* (ref. 12)
H20. Two-speed fans	Carrier Corp. (*Modudrive*)	FEA, *ECM-2* (ref. 12)
Hot water retrofits		
D1. Summer hot water heater	R. S. Means	Brookhaven boiler analysis (ref. 7)
D2. Flow controls	Omni Products, Inc., Yucca Valley, Calif.	ASHRAE Handbook (refs. 4 and 5)
D3. Insulate storage	R. S. Means	Carrier Corp., *System Design Manual* (ref. 8)
D4. Vent damper	Same source as H3	Brookhaven (ref. 7), NBS energy conservation modifications for water heaters
D5. Heat pump water heater	E-Tech., Inc., Atlanta, Ga.	Department of Energy, research and development of heat pump water heater (ref. 11)
Lighting retrofits		
L1. Fluorescent for incandescant	R. S. Means	McGuiness and Stein (ref. 15)
L2. Hybrid fluorescent	GE, *Circlight*, Los Angeles, Calif.	McGuiness and Stein (ref. 15)
L3. Task lighting	Dayton Co., commercial work fixtures	McGuiness and Stein (ref. 15)
L4. High-efficiency flourescent	GE (*Watt Mizer II*), Sylvania (*Superstar*)	McGuiness and Stein (ref. 15)
Solar retrofits	*References for Costs*, local contractors in Massachusetts cross-checked with R. S. Means, *Cost-Study Report to Mass-Save, Inc.*, 1981	*References for Savings*, 1) *Solar Heating Design by the F-Chart Method*, Beckman, Klein, Duffie, 1977, and 2) *Passive Solar Design Handbook*, vols. 1 and 2

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*Most of the algorithms used to estimate energy savings were developed by Energyworks, Inc. of West Newton, Mass., using parameters to be found in the sources cited. In a few cases, indicated here, the algorithm came from the source.

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Section M: Methodology for Calculating Energy Savings from Retrofit Packages

The following work, presented in Sections N through R, was carried out by Energyworks, Inc. in the Fall of 1981 in order to address the concerns of reviewers that some attempt had to be made to portray the results of retrofit packages, incorporating the interactions among energy retrofits. The results of the calculations are presented in Appendix B of the full report.

Energyworks found that the approach to this set of calculations had to be somewhat different from the approach used in calculating the savings from the individual retrofits. The calculations were performed only for the thirteen basic building types in the St. Louis climate zone. First, Energyworks made sensible combinations of retrofits into packages eliminating retrofits which would not normally be used in combination. The actual retrofits used for each package are listed in Appendix B.

Energyworks then calculated basic load profiles for each of the thirteen building types for five kinds of energy use: heating, cooling, hot water, auxiliary (fans, etc.) and lighting. The basic load profiles are shown in Section O. These load profiles should not be taken as typical of the building stock for each type of building. Rather they are calculated loads for uninsulated unretrofit buildings of each type. The loads in particular for frame houses are on the high side (350 annual MMBtu for a frame house with a water system). It should be remembered that these frame buildings are modelled as containing 2000 square feet; thus this load is 175 thousand Btu per square foot which is higher than typical but which should be characteristic of an uninsulated frame building maintained at 65°F in the winter and 75°F in the summer. The load profiles for the commercial and apartment buildings, while also for unimproved, unretrofit buildings, are also more typical of the energy use per square foot of such buildings.

To calculate the percentage savings from each retrofit package to each building type, Energyworks constructed algorithms for each retrofit in terms of eighteen basic parameters and then calculated the cumulative effect on each parameter from each retrofit package. The parameters and the impacts on them are shown in Section R. The algorithms used are listed in Section P and the computer program is listed in Section Q.

The revised load profiles for each retrofit package and each building type are shown in Section O. The "without factor" column shows the basic energy use, in million Btus, regardless of fuel type. The "with factor" column is the adjusted use, incorporating a factor of 2.461 to normalize the relative cost-per-Btu of electricity versus oil. The final column of each profile gives the annual energy budget in dollars, based on a rate of $7.143 per million fuel-adjusted Btus. The annual budgets are much higher than typical single family houses but should be thought of as the energy cost of maintaining a larger-than-average house at the target temperatures summer and winter rather than lowering thermostats or closing off rooms or not air conditioning rooms.

Section N: Costs and Savings from Retrofit Packages

This section shows the savings in annual million Btus and capital costs per annual million Btu of savings from packages of retrofit measures to thirteen building types in the St. Louis climate zone. The same calculations were presented in graphical form in Appendix B of the full report.

The savings shown are fuel-adjusted savings as explained in Section K. The packages are defined as follows:

> Low Capital Cost Compared to Savings: Includes individual retrofits from which fuel-adjusted savings cost less than $14 per annual million Btu saved.
>
> Moderate Capital Cost Compared to Savings: Includes individual retrofits for which fuel-adjusted savings cost between $14 and $49 per annual million Btus saved.
>
> High Capital Cost Compared to Savings: Includes individual retrofits for which fuel-adjusted savings cost between $49 and $105 per annual million Btu saved.

Because of interactive effects among the individual retrofits the cost/savings ratios for the packages are sometimes higher than the thresholds for the individual retrofits.

Load profiles for the thirteen building types for each of the packages, with and without the fuel adjustment factor, are shown in the next section, Section O.

For the moderate and high capital cost packages the calculated savings are based on an assumption that the lower cost savings have been achieved.

TABLE N1

Fuel-Adjusted Annual Savings and Cost per Annual Million Btu Saved for Thirteen Building Types in the St. Louis Climate Zone

	Base Energy Use (MMBtu/Year)*	Annual Savings (MMBtu*/Year)	Capital Cost Per Annual Million Btu Saved (Dollars)
Small Frame House			
Air System	575		
Low**		132	7.9
Moderate**		74	42.0
High**		10	91.0
Small Frame House			
Water System	628		
Low		179	8.3
Moderate		96	26.0
High		16	111.0
Small Frame House			
Dec. System	705		
Low		228	6.6
Moderate		114	24.0
High		19	289.0
Masonry House			
Air System	404		
Low		29	11.0
Moderate		30	50.0
High		41	153.0
Masonry House			
Water System	436		
Low		27	8.9
Moderate		87	30.0
High		36	141.0
Masonry House			
Dec. System	466		
Low		34	7.1
Moderate		123	28.0
High		19	440.0

---

* Fuel-adjusted

** Capital cost compared to savings

(continuation)

	Base Energy Use (MMBtu/Year)*	Annual Savings (MMBtu*/Year)	Capital Cost Per Annual Million Btu Saved (dollars)
Large Multi-Family Air System	12,985		
Low		4250	6.5
Moderate***		-	-
High		2570	123.0
Large Multi-Family Water System	13,950		
Low		3595	5.9
Moderate*		2586	40.0
High		1648	136.0
Large Multi-Family Dec. System	14,923		
Low		4054	8.9
Moderate		3655	57.0
High		1755	123.0
Commercial Building Air System	10,545		
Low		3327	26.0
Moderate		1406	58.0
High		1107	206.0
Commercial Building Water System	10,579		
Low		1724	6.6
Moderate		3277	58.0
High		1102	183.0
Commercial Building Dec. System	10,882		
Low		2941	3.9
Moderate		2962	61.0
High		645	300.0
Commercial Building Reheat System	13,705		
Low		5496	5.3
Moderate		1940	79.0
High		680	147.0

*** Moderate and high capital cost retrofit packages were combined for this building type.

Section O: Load Profiles for Thirteen Building Types in the St. Louis Climate Zone for Three Levels of Investment in Retrofit Packages

The following tables show load profiles which correspond to the savings estimates for the retrofit packages shown in the previous section, Section N. The "Low Investment Level" of this table is the same as the "Low Capital Cost Compared to Savings" of the previous table.

One set of figures was revised following the preparation of this table. For all of the small frame houses the estimates of savings from the wall insulation component of the low retrofit package are too high. In a sample recalculation, Energyworks reduced the heating load of the low investment package only to 106 MMBtu (instead of 64 MMBtu as shown) and the cooling load only to 214 MMBtu fuel-adjusted (instead of 197 MMBtu fuel-adjusted). This revised estimate was incorporated into the discussion of wall insulation in Chapter 3 of the full report. The calculations affected are marked with an * in the table.

TABLE 5 - LOAD PROFILES

BUILDING TYPE: CAV/AIR/1

BASE INVESTMENT LEVEL

	WITH FACTOR	WITHOUT FACTOR	COST ($)
HEATING	173	173	1236
COOLING	191	77	1364
HVAC AUX.	13	5	98
LIGHTS	174	71	1248
DHW	23	23	165
TOTAL	575	350	4113

LOW INVESTMENT LEVEL

	WITH FACTOR	WITHOUT FACTOR	COST ($)
HEATING	87*	87*	627
COOLING	159	64	1136
HVAC AUX.	11	4	79
LIGHTS	174	71	1248
DHW	10	10	78
TOTAL	443	238	3169

MEDIUM INVESTMENT LEVEL

	WITH FACTOR	WITHOUT FACTOR	COST ($)
HEATING	38	38	277
COOLING	136	55	976
HVAC AUX.	11	4	79
LIGHTS	174	71	1248
DHW	8	8	59
TOTAL	369	178	2640

HIGH INVESTMENT LEVEL

	WITH FACTOR	WITHOUT FACTOR	COST ($)
HEATING	32	32	231
COOLING	133	54	953
HVAC AUX.	11	4	79
LIGHTS	174	71	1248
DHW	8	8	59
TOTAL	359	170	2571

BUILDING TYPE: CAV/H20/1

BASE INVESTMENT LEVEL

	WITH FACTOR	WITHOUT FACTOR	COST ($)
HEATING	173	173	1236
COOLING	255	103	1822
HVAC AUX.	2	1	17
LIGHTS	174	71	1248
DHW	23	23	165
TOTAL	628	371	4490

LOW INVESTMENT LEVEL

	WITH FACTOR	WITHOUT FACTOR	COST ($)
HEATING	64*	64*	459
COOLING	197	80	1409
HVAC AUX.	2	1	17
LIGHTS	174	71	1248
DHW	10	10	78
TOTAL	449	227	3213

MEDIUM INVESTMENT LEVEL

	WITH FACTOR	WITHOUT FACTOR	COST ($)
HEATING	41	41	299
COOLING	123	50	884
HVAC AUX.	2	1	17
LIGHTS	174	71	1248
DHW	10	10	78
TOTAL	353	175	2527

HIGH INVESTMENT LEVEL

	WITH FACTOR	WITHOUT FACTOR	COST ($)
HEATING	29	29	211
COOLING	119	48	852
HVAC AUX.	2	1	17
LIGHTS	174	71	1248
DHW	10	10	78
TOTAL	337	161	2407

BUILDING TYPE: CAV/DEC/1

BASE INVESTMENT LEVEL

	WITH FACTOR	WITHOUT FACTOR	COST ($)
HEATING	247	100	1764
COOLING	255	103	1822
HVAC AUX.	0	0	0
LIGHTS	174	71	1248
DHW	28	11	201
TOTAL	705	286	5036

LOW INVESTMENT LEVEL

	WITH FACTOR	WITHOUT FACTOR	COST ($)
HEATING	91*	37*	656
COOLING	197	80	1409
HVAC AUX.	0	0	0
LIGHTS	174	71	1248
DHW	13	5	97
TOTAL	477	194	3410

MEDIUM INVESTMENT LEVEL

	WITH FACTOR	WITHOUT FACTOR	COST ($)
HEATING	54	22	387
COOLING	120	49	862
HVAC AUX.	0	0	0
LIGHTS	174	71	1248
DHW	13	5	97
TOTAL	363	147	2595

HIGH INVESTMENT LEVEL

	WITH FACTOR	WITHOUT FACTOR	COST ($)
HEATING	34	14	249
COOLING	120	49	862
HVAC AUX.	0	0	0
LIGHTS	174	71	1248
DHW	13	5	97
TOTAL	344	139	2458

BUILDING TYPE: MBW/AIR/1

BASE INVESTMENT LEVEL

	WITH FACTOR	WITHOUT FACTOR	COST ($)
HEATING	64	64	462
COOLING	128	52	916
HVAC AUX.	13	5	98
LIGHTS	174	71	1248
DHW	23	23	165
TOTAL	404	216	2890

LOW INVESTMENT LEVEL

	WITH FACTOR	WITHOUT FACTOR	COST ($)
HEATING	51	51	369
COOLING	127	51	909
HVAC AUX.	11	4	79
LIGHTS	174	71	1248
DHW	10	10	78
TOTAL	375	189	2684

MEDIUM INVESTMENT LEVEL

	WITH FACTOR	WITHOUT FACTOR	COST ($)
HEATING	30	30	219
COOLING	118	48	845
HVAC AUX.	11	4	79
LIGHTS	174	71	1248
DHW	10	10	78
TOTAL	345	165	2470

HIGH INVESTMENT LEVEL

	WITH FACTOR	WITHOUT FACTOR	COST ($)
HEATING	3	3	25
COOLING	104	42	743
HVAC AUX.	11	4	79
LIGHTS	174	71	1248
DHW	10	10	78
TOTAL	304	132	2174

BUILDING TYPE: MBW/H20/1

BASE INVESTMENT LEVEL

	WITH FACTOR	WITHOUT FACTOR	COST ($)
HEATING	64	64	448
COOLING	171	69	1220
HVAC AUX.	2	1	17
LIGHTS	174	71	1248
DHW	23	23	165
TOTAL	436	229	3581

LOW INVESTMENT LEVEL

	WITH FACTOR	WITHOUT FACTOR	COST ($)
HEATING	52	52	372
COOLING	169	68	1211
HVAC AUX.	2	1	17
LIGHTS	174	71	1248
DHW	10	10	78
TOTAL	409	204	2928

MEDIUM INVESTMENT LEVEL

	WITH FACTOR	WITHOUT FACTOR	COST ($)
HEATING	28	28	203
COOLING	105	42	753
HVAC AUX.	2	1	17
LIGHTS	174	71	1248
DHW	10	10	78
TOTAL	322	154	2301

HIHG INVESTMENT LEVEL

	WITH FACTOR	WITHOUT FACTOR	COST ($)
HEATING	5	5	36
COOLING	93	37	667
HVAC AUX.	2	1	17
LIGHTS	174	71	1248
DHW	10	10	78
TOTAL	286	126	2048

BUILDING TYPE: MBW/DEC/1

BASE INVESTMENT LEVEL

	WITH FACTOR	WITHOUT FACTOR	COST ($)
HEATING	93	37	665
COOLING	170	69	1220
HVAC AUX.	0	0	0
LIGHTS	174	71	1248
DHW	28	11	201
TOTAL	466	189	3335

LOW INVESTMENT LEVEL

	WITH FACTOR	WITHOUT FACTOR	COST ($)
HEATING	74	30	532
COOLING	169	68	1211
HVAC AUX.	0	0	0
LIGHTS	174	71	1248
DHW	13	5	97
TOTAL	432	175	3089

MEDIUM INVESTMENT LEVEL

	WITH FACTOR	WITHOUT FACTOR	COST ($)
HEATING	23	9	165
COOLING	98	39	700
HVAC AUX.	0	0	0
LIGHTS	174	71	1248
DHW	13	5	97
TOTAL	309	125	2211

HIGH INVESTMENT LEVEL

	WITH FACTOR	WITHOUT FACTOR	COST ($)
HEATING	8	3	60
COOLING	93	37	667
HVAC AUX.	0	0	0
LIGHTS	174	71	1248
DHW	13	5	97
TOTAL	290	117	2074

BUILDING TYPE: CLAD/AIR/4

BASE INVESTMENT LEVEL

	WITH FACTOR	WITHOUT FACTOR	COST ($)
HEATING	2572	2572	18374
COOLING	2828	1149	20201
HVAC AUX.	1028	418	7347
LIGHTS	3730	1516	26649
DHW	385	385	2754
TOTAL	10545	6041	75327

LOW INVESTMENT LEVEL

	WITH FACTOR	WITHOUT FACTOR	COST ($)
HEATING	1875	1875	13400
COOLING	1841	748	13155
HVAC AUX.	821	334	5871
LIGHTS	2569	1044	18352
DHW	109	109	781
TOTAL	7218	4111	51560

MEDIUM INVESTMENT LEVEL

	WITH FACTOR	WITHOUT FACTOR	COST ($)
HEATING	884	884	6316
COOLING	1427	579	10194
HVAC AUX.	821	334	5871
LIGHTS	2569	1044	18352
DHW	109	109	781
TOTAL	5812	2951	41515

HIGH INVESTMENT LEVEL

	WITH FACTOR	WITHOUT FACTOR	COST ($)
HEATING	141	141	1009
COOLING	1063	432	7595
HVAC AUX.	821	334	5871
LIGHTS	2569	1044	18352
DHW	109	109	781
TOTAL	4705	2060	33610

BUILDING TYPE: CLAD/H20/4

BASE INVESTMENT LEVEL

	WITH FACTOR	WITHOUT FACTOR	COST ($)
HEATING	2196	2196	1568
COOLING	4001	1625	2858
HVAC AUX.	265	108	1898
LIGHTS	3730	1516	2664
DHW	385	385	2754
TOTAL	10579	5831	7557

LOW INVESTMENT LEVEL

	WITH FACTOR	WITHOUT FACTOR	COST ($)
HEATING	1333	1333	9521
COOLING	3800	1544	2714
HVAC AUX.	265	108	1898
LIGHTS	3346	1360	2390
DHW	109	109	781
TOTAL	8855	4454	6325

MEDIUM INVESTMENT LEVEL

	WITH FACTOR	WITHOUT FACTOR	COST ($)
HEATING	783	783	5598
COOLING	1850	751	1321
HVAC AUX.	265	108	1898
LIGHTS	2569	1044	1835
DHW	109	109	781
TOTAL	5578	2796	3984

HIGH INVESTMENT LEVEL

	WITH FACTOR	WITHOUT FACTOR	COST ($)
HEATING	93	93	670
COOLING	1438	584	1027
HVAC AUX.	265	108	1898
LIGHTS	2569	1044	1835
DHW	109	109	781
TOTAL	4476	1939	3197

BUILDING TYPE: CLAD/DEC/4

BASE INVESTMENT LEVEL

	WITH FACTOR	WITHOUT FACTOR	COST ($)
HEATING	2810	1142	20077
COOLING	4001	1625	28580
HVAC AUX.	0	0	0
LIGHTS	3730	1516	26649
DHW	339	137	2425
TOTAL	10882	4421	77733

LOW INVESTMENT LEVEL

	WITH FACTOR	WITHOUT FACTOR	COST ($)
HEATING	885	359	6326
COOLING	3160	1284	22572
HVAC AUX.	0	0	0
LIGHTS	3730	1516	26649
DHW	164	66	1175
TOTAL	7941	3226	56724

MEDIUM INVESTMENT LEVEL

	WITH FACTOR	WITHOUT FACTOR	COST ($)
HEATING	640	260	4577
COOLING	1604	651	11460
HVAC AUX.	0	0	0
LIGHTS	2569	1044	18352
DHW	164	66	1175
TOTAL	4979	2023	35566

HIGH INVESTMENT LEVEL

	WITH FACTOR	WITHOUT FACTOR	COST ($)
HEATING	161	65	1155
COOLING	1438	584	10275
HVAC AUX.	0	0	0
LIGHTS	2569	1044	18352
DHW	164	66	1175
TOTAL	4334	1761	30959

BUILDING TYPE: CLAD/COMP/4

BASE INVESTMENT LEVEL

	WITH FACTOR	WITHOUT FACTOR	COST ($)
HEATING	2057	2057	1469
COOLING	2828	1149	2020
HVAC AUX.	1028	418	7347
LIGHTS	3730	1516	2664
DHW	385 3674	385 3674	2754 2624
TOTAL	~~10031~~ 13705	~~5526~~ 9200	~~7165~~ 978

LOW INVESTMENT LEVEL

	WITH FACTOR	WITHOUT FACTOR	COST ($)
HEATING	1452	1452	103
COOLING	2265	920	161
HVAC AUX.	1028	418	734
LIGHTS	3346	1360	239
DHW	114	114	821
TOTAL	8209	4266	586

MEDIUM INVESTMENT LEVEL

	WITH FACTOR	WITHOUT FACTOR	COST ($)
HEATING	927	927	662
COOLING	1634	664	116
HVAC AUX.	1028	418	734
LIGHTS	2569	1044	183
DHW	109	109	781
TOTAL	6269	3162	447

HIGH INVESTMENT LEVEL

	WITH FACTOR	WITHOUT FACTOR	COST ($)
HEATING	462	462	330
COOLING	1420	577	101
HVAC AUX.	1028	418	734
LIGHTS	2569	1044	183
DHW	109	109	781
TOTAL	5589	2610	399

BUILDING TYPE: CLAD/AIR/5

BASE INVESTMENT LEVEL

	WITH FACTOR	WITHOUT FACTOR	COST ($)
HEATING	2853	2853	20383
COOLING	4027	1636	28765
HVAC AUX.	947	385	6767
LIGHTS	3145	1278	22465
DHW	2011	2011	14370
TOTAL	12985	8164	92752

LOW INVESTMENT LEVEL

	WITH FACTOR	WITHOUT FACTOR	COST ($)
HEATING	2793	2793	19956
COOLING	2785	1131	19898
HVAC AUX.	757	308	5414
LIGHTS	1562	635	11162
DHW	835	835	5969
TOTAL	8735	5704	62400

MEDIUM INVESTMENT LEVEL

	WITH FACTOR	WITHOUT FACTOR	COST ($)
HEATING	2535	2535	18108
COOLING	2555	1038	18251
HVAC AUX.	757	308	5414
LIGHTS	1562	635	11162
DHW	835	835	5969
TOTAL	8246	5351	58905

HIGH INVESTMENT LEVEL

	WITH FACTOR	WITHOUT FACTOR	COST ($)
HEATING	926	926	6619
COOLING	2082	846	14877
HVAC AUX.	757	308	5414
LIGHTS	1562	635	11162
DHW	835	835	5969
TOTAL	6165	3551	44042

BUILDING TYPE: CLAD/H20/5

BASE INVESTMENT LEVEL

	WITH FACTOR	WITHOUT FACTOR	COST ($)
HEATING	2422	2422	17304
COOLING	5744	2334	41035
HVAC AUX.	265	108	1898
LIGHTS	3145	1278	22465
DHW	2011	2011	14370
TOTAL	13590	8154	97074

LOW INVESTMENT LEVEL

	WITH FACTOR	WITHOUT FACTOR	COST ($)
HEATING	2150	2150	15359
COOLING	5181	2105	37011
HVAC AUX.	265	108	1898
LIGHTS	1562	635	11162
DHW	835	835	5969
TOTAL	9995	5834	71401

MEDIUM INVESTMENT LEVEL

	WITH FACTOR	WITHOUT FACTOR	COST ($)
HEATING	1508	1508	10778
COOLING	3236	1314	23115
HVAC AUX.	265	108	1898
LIGHTS	1562	635	11162
DHW	835	835	5969
TOTAL	7409	4402	52924

HIGH INVESTMENT LEVEL

	WITH FACTOR	WITHOUT FACTOR	COST ($)
HEATING	424	424	3035
COOLING	2672	1085	19087
HVAC AUX.	265	108	1898
LIGHTS	1562	635	11162
DHW	835	835	5969
TOTAL	5761	3089	41152

```
BUILDING TYPE: CLAD/DEC/5

BASE INVESTMENT LEVEL

              WITH       WITHOUT      COST
              FACTOR     FACTOR        ($)

HEATING       3219       1308         22996
COOLING       5744       2334         41035
HVAC AUX.     0          0            0
LIGHTS        3145       1278         22465
DHW           2814       1143         20102

TOTAL         14923      6064         106600

LOW INVESTMENT LEVEL

              WITH       WITHOUT      COST
              FACTOR     FACTOR        ($)

HEATING       3386       1376         24192
COOLING       5181       2105         37011
HVAC AUX.     0          0            0
LIGHTS        1562       635          11162
DHW           738        300          5275

TOTAL         10889      4416         77641

MEDIUM INVESTMENT LEVEL

              WITH       WITHOUT      COST
              FACTOR     FACTOR        ($)
HEATING       1677       681          11979
COOLING       3236       1314         23115
HVAC AUX.     0          0            0
LIGHTS        1562       635          11162
DHW           738        300          5275

TOTAL         7214       2931         51532

HIGH INVESTMENT LEVEL

              WITH       WITHOUT      COST
              FACTOR     FACTOR        ($)

HEATING       485        197          3469
COOLING       2672       1085         19087
HVAC AUX.     0          0            0
LIGHTS        1562       635          11162
DHW           738        300          5275

TOTAL         5459       2218         38995
```

Section P: Algorithms Used in Calculating the Cumulative Savings of Retrofits Combined in Packages

This section presents the algorithms used in the calculations of cumulative savings from packages of retrofits. The algorithms are designed to include only the parameters described in Section R for the reasons outlined in Section M.

ENVELOPE RETROFITS

E1 - Roof Insulation

Parameters Affected: UA

Algorithm

$$\left.\begin{array}{ll}\text{P/U 1:} & \text{Add R-19}\\ \text{Others:} & \text{Add R-15}\end{array}\right\} \quad \Delta UA = \left(U_r - \frac{1}{1/U_R + \left\{\begin{smallmatrix}19\\15\end{smallmatrix}\right\}}\right) \times A_r$$

	U_{roof}	A_{roof}	UA
P/U 1A	.21	1000	168
P/U 1B	.21	1000	168
P/U 4C	.211	12500	2004
P/U 5C	.211	12500	2004

E2 - Wall Insulation

Parameters Affected: UA

Algorithm: R = 13

$$UA = \left(U_{wall} - \frac{1}{1/U_{wall} + 13}\right) \times A_{wall}$$

$$UA^1 = UA_o - \left(\left(U_W - \frac{1}{1/U_w + 13}\right) \times A_W\right.$$

Factors	UA	UA '
P/U 1A: U_W - .306, A_W = 1820	445	
P/U 1B: U_W = .257, A_W = 880	174	
P/U 4C: U_W = .288, A_W = 25200	5728	
P/U 5C: U_W = .288, A_W = 40800	9274	

E-3 STORM WINDOWS

Parameters: UA, IW%, IS%

Algorithm: Reduce - Uw by 50%
Reduce - Infiltration coefficient by 30%

$\Delta UA = Uw \times Aw \times .5$
$\Delta IW\% = IW\% \times .3$
$\Delta IS\% = IS\% \times .3$

	Uw	Aw	IW%	IS%	ΔUA	Δ IW%	Δ IS%
P/U 1A	.961	260	76	58	125	23	17
P/U 1B	.961	120	45	35	58	14	11
P/U 4C	1.13	10800	2330	726	6102	699	218
P/U 5C	1.13	7200	1376	1105	4068	413	332

E-5 WEATHERSTRIPPING

Parameters: IW%, IS%

Algorithm: Reduce Infiltration by 40%

with storm windows:

Reduce remaining infil. = .7 x .4 = 28%

	BASE, E-5 ONLY		CUMULATIVE W/STORMS	
	Δ IW%	ΔIS%	Δ IW%	ΔIS%
P/U 1A	30	23	44	34
P/U 1B	18	14	26	20
P/U 4C	932	290	1351	421
P/U 5C	550	442	798	641

E-6 WINDOW INSULATION

Parameters: UA

Algorithm: Add R-3, Storm windows assumed

$U = .3857$, $DD_{night}/DD_{total} = .652$, Use Factor = .75

$\Delta UA = A \times .3857 \times .652 \times .75 = A \times .1885$

	ΔUA
P/U 1A	49
P/U 1B	23
P/U 4C	2036
P/U 5C	1357

E-8 SHADING DEVICES

Use same algorithm as storm windows + reduce SHG by 25% of original

---

E-9 ROOF SPRAY

Reduce summer SHG by 10%

	SW	SS
P/U 1A	11.1	11.3
P/U 1B	5.3	3.3
P/U 4C	459	468
P/U 5C	306	312

HEATING SYSTEM RETROFITS

H-3, H-1, H-7, H-6, H-13

Parameter: HE%

SIMPLIFIED HEATING EFFICIENCY CURVES

		BASE	H-3 VENT DAMPER	H-1 NEW BURNER	MOD. AQUASTAT	REHEAT VAV	H-6 TURBU-LATORS	H-3 + H-7 + H-1	H-3 + H-13
P/U 1	Low Use	.58	.62	.68	.68	X	ADD	.78	
	High Use	.65	.68	.71	.70		2%	.78	
P/U 4	L	.52	.55	.65	.61	BASE .65		.70	
	H	.55	.58	.69	.63	NEW .75		.72	
P/U 5	L	.54	.57	.67	.64	X		.74	
	H	.58	.60	.71	.66			.76	

H-5 Heat Pumps

Parameters: HE, CE

Algorithm: New CE = 1.73 without H-10 only
New HE = 1.55 for St. Louis (vs.1.0)

NOTE: With H-10, assume new room AC units retained for cooling, CE = 2.27

H-8 Thermostats

Parameters: Heating Deg-Days HD%

Algorithm:

Commercial: HD%' = 2973 P/U 4C
Residential: HD%' = 3371 P/U 1A, 1B, 5C

H-9 Enthalpy Control

Parameters: Cooling Deg-Days CD%

Algorithm: Approximated as effective reduction in cooling degree-days CD%, on basis of outside air cooling potential.

Equiv. DD = 256, assume 80% usable = 205

Net CDD = 2337 - 205 = 2132

H-10 Replace Room AC

Parameters: Seasonal COP (CE)

Algorithm: New C old COP's from table (original)

	SCOP	SCOP'
P/U 1A	1.52	2.27
P/U 1B	1.52	2.27
P/U 4C	1.52	2.27
P/U 5C	1.52	2.27

H-12 Vary CHW Temperature

Parameters: CE

Algorithm: 20% effective load reduction (from original algorithm)

$$\text{Effective new } CE' = \frac{CE}{1-.20} = \frac{CE}{.8} = 1.25 \times CE$$

P/U 4, 5, Air Systems: $CE = 2.26$

$CE' = 2.825$

H-13 CONVERT REHEAT TO VAV

Revised
P/U 4C only

Old Algorithm: Raise HE .65 → .75

New: New parameter for reheat energy - RH (MMBTU)

Reheat heating loads (base load subtracted):

Winter: (((207.3 X TSCFM) - (74.1 X VCFM)) X LHS)

Summer: 46.3 X TSCFM X LCS

$$\text{where TSCF} = \frac{\text{PCL (BTU)}}{1.08 \text{ X } 25^\circ} = \frac{4665956}{21.6} = 172{,}800$$

$$\text{Adjust for time-on of system} = \frac{50 \text{ hrs}}{168 \text{ hrs}} = .298$$

Reheat Energy, Based on Equation from Attachment L

Winter: (((207.3 X 172800) - (74.1 X 3810)) X 185) = 6575 MMBTU

Summer: 46.3 X 172,800 X 180 = 1440 MMBTU

TOTAL = 8015 MMBTU X .298 - 2388 MMBTU

Revise HE: Reduced from .65 to .60 @ low, up to .62 @ MED

$$\text{Net Fuel Consumption} = \frac{2388}{.65} = 3674 \text{ MMBTU}$$

Cost = 3674 X $7.143 - $26,240

NOTE: HE (seas. heating efficiency) drops with implementation of reheat - VAV conversion to reflect reduction of seasonal operating time, thus increasing off-cycle losses.

H-14 REDUCE VENTILATION

Parameters: Ventilation CFM = VC%

Algorithm: Reduce VC% - 7.5 to 5.0 CFM/Pers. occupied hrs. (HV)
Reduce leakage 10% to 1 % unoccupied hrs.

$$\text{Effective reduction} = \left[.33 + \left(.09 \times \frac{168 - HV}{HV}\right)\right] \times VC\%$$

HV = 60 P/U 4, 168 P/U 5

% Reduction = .492 for P/U 4, .33 for P/U 5

	Base VC%	VC%'
P/U 4C	7500	3810
P/U 5C	6000	4020

APPLICABLE TO AIR & COMP. SYSTEMS ONLY

H-16 WATER-COOLED CONDENSER

Parameters: CE

Algorithm: $\text{Orig. savings} = SCL \times \frac{1}{CE} \times \left(1 - \frac{1}{1 + CCSS}\right)$ where CCSS = .175 (for St. Louis)

$$= \frac{SCL}{CE} \times .149$$

Effective increase in CE: $CE' = \frac{CE}{1-.149} = \frac{CE}{.851} = 1.175 \times CE$

Base Savings - CE = 2.26, $CE' = 2.66$

With H-12 - $CE' = \frac{CE}{.8 \times .851} \times .90$ interaction factor = 2.99

H-18 INSULATE DUCTS

Parameters: UA

Algorithm: Approximate as 2% envelope load reduction,

$UA' = .98 \times UA$, or $\Delta UA = .02 \times UA$

	BASE UA	ΔUA
P/U 1A	1177	24
P/U 1B	622	12
P/U 4C	22789	456
P/U 5C	23317	466

H-20 2-SPEED FANS

Parameters: FA (Fan energy use)

Algorithm: Base Fan Energy

P/U 4C, 5C: 20 HP Fan Motors (3 Phase) =

20 x .746 x $\sqrt{3}$ = 25.8 KW

Operating Times

P/U 4C: (50 hr/wk x 100%) + (118 hr/wk x 35%) = 54.3% ne

P/U 5C: 50% overall

Base Use = 25.8 KW x 168 x 52 x % x .003413
= 418 for P/U 4C MMBTU
= 385 for P/U 5C MMBTU

P/U 1A, 1B: 50% time x 1/2 HP (1 Phase) = 5.6 MMBTU

Reduction: Assume 20% reduction in fan power

	FA	FA'	MMBTU
P/U 1A	5.6	4.5	
P/U 1B	5.6	4.5	
P/U 4C	418	334	
P/U 5C	385	308	

HVAC AUXILIARY ENERGY FOR WATER SYSTEMS

P/U 1: 1/6 HP Circ. Pump, 50% oper.

P/U 4, 5: 10 HP Circ. Pump, 55% net oper.

} Heating Season Only

P/U 1: 1/6 x .746 x 24 x .5 x 185 days x .003413

= 1.0 MMBTU (FA)

P/U 4, 5: 10 x .746 x 24 x .55 x $\sqrt{3}$ x 185 x .003413

= 108 MMBTU (FA)

ENTHALPY CONTROL COOLING POTENTIAL

Outside - air cooling potential Apr. 15 - Oct. 15 - Daytime Only

Range Midpoint	Total Hrs.	ΔT vs. 77	DEG-HRS = 6140 DEG-DAYS = 256
72	244	5	
67	133	10	
62	82	15	
57	54	20	
52	32	25	
47	16	30	

HOT WATER SYSTEM RETROFITS

D-2 FLOW CONTROLS

Parameters: GA%

Algorithm: Reduce by 50%

	GA%	GA%
P/U 1A	294	147
P/U 1B	294	147
P/U 4C	7000	3500
P/U 5C	29400	14700

D-3 INSULATE STORAGE

Parameters: WE (DHW Seas. efficiency)

Algorithm: 5% increase in WE above base level

$WE' = WE \times 1.05$

	WE	WE'
P/U 1A	.47	.494
P/U 1B	.47	.494
P/U 4C	.34	.357
P/U 5C	.54	.567

D-4 DHW VENT DAMPER

Parameters: WE

Algorithm:

Without D-3: Use vent damper WE from tables
With D-3: Use same % increase over revised WE

	WE	Without D-3	With D-3
P/U 1A	.47	.62	.652
P/U 1B	.47	.62	.652
P/U 4C	.34	.57	.599
P/U 5C	.54	.65	.683

D-5 DHW HEAT PUMP

Parameters: WE

Algorithm: For DEC systems only

Commercial: 115° outlet, " ", $COP_{ss} = 2.95$

Residential: Same COP, backup required above 115°

$60^\circ \longrightarrow 115^\circ$ = 68% of load
$115^\circ \longrightarrow 140^\circ$ = 32% of load

$$\frac{1}{E_{net}} = \left(\frac{1}{E_{backup}} \times \% \text{ backup}\right) + \left(\frac{1}{E_{HP}} \times \% \text{ HP}\right) = \frac{.32}{1} + \frac{.69}{2.95} = .55$$

$E_{net} = 1.81$

Adjust all efficiencies by .95 for uninsulated storage

	BASE	HP ONLY	HP + D-3
P/U 1A	.95	1.72	1.81
P/U 1B	.95	1.72	1.81
P/U 4C	.95	2.80	2.95
P/U 5C	.95	1.72	1.81

LIGHTING RETROFITS

L-2 HYBRID LAMPS

Parameters: KR, KC, LW, LS

Algorithm:

$$KR' = KR \times .33 \text{ Commer.}$$
$$= KR \times ((.33 \times .70) + (1 \times .3)) = KR \times .531 \text{ Resid.}$$

$$KC' = KC \times .33$$

$$LW' = LW \times .33 \text{ Commer.}$$
$$= LW \times \left[(.33 \times \frac{KC}{KR + KC}) + (.531 \times \frac{KR\ .}{KR + KC})\right] \text{ Resid.}$$

	KR	KC	LW	LS	KR'	KC'	LW'	LS'
P/U 4C	400	20	2322	2259	132	6.6	766	745
P/U 5C	100	20	648	630	53	6.6	322	313

L-3 TASK LIGHTING

Parameters: KR, LW, LS P/U 4C Only

Algorithm: KW reduction = 96.1 (incandescent)
= 96.1 x .33 = 31.7 w/L-2 ⟵

Occurs only with L-2

$$KR'' = KR' - 32$$
$$LW'' = LW' \times \left[\frac{KR' + KC' - 32}{KR' + KC'}\right] = LW' \times .7691$$

	KR''	KC''	LW''	LS''
P/U 4C	100	6.6	589	573

Section Q: Computer Program Used in Calculating Savings from Retrofit Packages

This section presents the computer program used by Energyworks in calculating the savings from the retrofit packages presented in the earlier sections.

APPENDIX A - INTERACTIVE PROGRAM LISTING

```
10  REM  OTA 8/81 PROGRAM
20  REM  INTERACTIVE RECALCULATIO
    N
120  REM  CLIMATE DATA
122  REM  HD%= HEATING DEGREE-DAY
     S
124  REM  CD%= COOLING DEGREE-DAY
     S
126  REM  LH%= LENGTH OF HTING.SE
     ASON, DAYS
128  REM  LC%= LENGTH OF COOLING
     SEASON, DAYS
140  READ HD%,CD%,LH%,LC%
160  DATA  3628,2337,185,180
180  REM  OCCUPANCY DATA
182  REM  OM%= MAX.OCCUPANCY
184  REM  HO= EQ.MAX.OCC.HOURS/WE
     EK
186  REM  HR= EQ.MAX.HRS/WK, ROOM
      LIGHTING
188  REM  HC= EQ.MAX.HRS/WK, CORR
     IDOR LIGHTING
200  READ OM%,HO,HR,HC
220  DATA  330,134,38.2,168
240  REM  MISC & PEAK LOADS
242  REM  EH= EQUIP.HEAT GAIN,MMB
     TU/WK
244  REM  WT%= DHW SUPPLY TEMP.
246  REM  PD= DHW PEAK LOAD, MMBT
     U/HR
248  REM  PH= PEAK HEATING LOAD,M
     MBTU
250  REM  PC= PEAK COOLING LOAD,M
     MBTU
260  READ EH,WT%,PD,PH,PC
280  DATA  21.9,140,.709,1.9,1.62
284  REM
285  REM  INPUT VARIABLE PARAMETE
     RS
286  REM
290  PRINT : PRINT : PRINT "PRESS
      RETURN TO CHANGE HEATING DD
     ,": PRINT "ANY OTHER KEY TO
     USE DEFAULT": GET DD$
295  IF  ASC (DD$) <  > 13 THEN 3
     05
300  INPUT "HEATING DD= ";HD%
305  PRINT : PRINT "PRESS RETURN
     TO CHANGE COOLING DD,": PRINT
     "ANY OTHER KEY TO USE DEFAUL
     T": GET DD$
310  IF  ASC (DD$) <  > 13 THEN 3
     16
315  INPUT "COOLING DD= ";CD%
316  PRINT : PRINT
320  INPUT "BLDG.UA= ";UA: INPUT
     "WINTER SOLAR HG(MMBTU)= ";S
     W: INPUT "SUMMER SOLAR HG(MM
     BTU)= ";SS
```

```
360  INPUT "INFIL.CFM,WINTER= ";I
     W%: INPUT "INFIL.CFM,SUMMER=
      ";IS%: INPUT "VENT.CFM= ";V
     C%: INPUT "VENT.OP.HR/WK= ";
     HV
400  INPUT "ROOM LTNG.KW= ";KR: INPUT
     "CORRIDOR LTNG.KW= ";KC: INPUT
     "DHW GAL/WK= ";GA%: INPUT "L
     TNG.HT.GAIN MMBTU,WINTER= ";
     LW: INPUT "LTNG.HT.GAIN MMBT
     U,SUMMER= ";LS
410  PRINT : PRINT "ENTER 1 IF DE
     CENTRALIZED SYSTEM,": PRINT
     "0 FOR ANY OTHER TYPE": INPUT
     "  -->";DC%
434  REM
435  REM  BEGIN CALC. ROUTINES
436  REM
440  REM  LIGHTING
460 LB = LW + LS: REM  LTNG.MMBTU
     ,BASE
480 LF = LB * 2.461: REM   LTNG.M
     MBTU, WITH FUEL FACTOR
500 LC = LF * 7.143: REM   LTG.CO
     ST
520  REM  HEATING
540 SH = (((HD% * 24 * (UA + 1.08
      * (IW% + (VC% * HV / 168)))
     ) - (LH% * OM% * HO * 57.14)
     ) * 10 ^  - 6) - .75 * (LW +
     SW)
560  PRINT "SEAS.HEAT LOAD= ";SH;
     " MMBTU"
580 FH = 1.25
600 HP = SH / (PH * FH * 24 * LH%
     )
620  PRINT "% ON-TIME= ";HP
630  PRINT
640  INPUT "SEAS.EFFIC.= ";HE
650  PRINT
660 HB = SH / HE: REM    HTNG.MMB
     TU
665  IF  NOT DC% THEN 675
670 HF = HB * 2.461: GOTO 680: REM
              MMBTU,WITH ELEC
     .FUEL FACTOR
675 HF = HB
680 CH = HF * 7.143: REM   HTNG.C
     OST
700  REM   COOLING
720 SC = (((CD% * 24 * (UA + 1.08
      * (IS% + (VC% * HV / 168)))
     ) + (((OM% * HO * 400) + (EH
      * 10 ^ 6)) * LC% / 7)) * 10
      ^  - 6) + LS + SS
760 FC = 1.25
780 CP = SC / (PC * FC * 24 * LC%
     )
820  INPUT "SEASONAL COOLING COP=
      ";CE
830  PRINT
```

```
840 CF = SC / CE: REM   COOLING M
    MBTU
860 C2 = CF * 2.461: REM   COOLIN
    G            MMBTU, WITH FU
    EL FACTOR
880 CC = C2 * 7.143: REM   COOLIN
    G COST
900  REM  DOMESTIC HOT WATER
920  PRINT "INPUT 1 FOR RESID., 0
      FOR COMMER.": INPUT IND%
940 DH = GA% * (WT% - 55) * 1.191
      * 10 ^  - 6 * (LH% + (IND% *
     180))
960 DP = DH / (PD * 24 * (LH% + (
     IND% * 620)))
980  PRINT
1000  INPUT "DHW SEAS.EFFIC.= ";W
     E
1010  PRINT
1020 DB = DH / WE: REM   DHW MMBT
     U
1025  IF  NOT DC% THEN 1035
1030 DF = DB * 2.461: GOTO 1040: REM
               MMBTU,WITH ELEC.F
     UEL FACTOR
1035 DF = DB
1040 DC = DF * 7.143: REM   DHW C
     OST
1042  INPUT "HVAC AUXILIARY LOAD=
      ";FA
1044 F2 = FA * 2.461: REM  HVAC A
     UX.,WITH FUEL FACTOR
1045  REM  OUTPUT PROGRAM
1046 F3 = F2 * 7.143: REM  HVAC A
     UX.COST
1049  REM  OUTPUT PROGRAM
1050  PRINT : INPUT "NAME OF BLDG
     .TYPE: ";BT$
1055  INPUT "INVESTMENT LEVEL: ";
     IL$
1060  REM  OUTPUT PROGRAM
1080  PR# 1
1090  IF IL$ <  > "BASE" THEN 111
     0
1095  PRINT : PRINT
1100  PRINT  TAB( 13)"LOAD PROFIL
     ES": PRINT "BUILDING TYPE: "
     ;BT$
1110  PRINT : PRINT : PRINT IL$;"
      INVESTMENT LEVEL"
1120  PRINT : PRINT  TAB( 12)"WIT
     H"; TAB( 22)"WITHOUT"; TAB(
     34)"COST"
1130  PRINT  TAB( 12)"FACTOR"; TAB(
     22)"FACTOR"; TAB( 35)"($)"
1140  PRINT : PRINT "HEATING"; TAB(
     12) INT (HF); TAB( 22) INT (
     HB); TAB( 34) INT (CH)
1160  PRINT "COOLING"; TAB( 12) INT
     (C2); TAB( 22) INT (CF); TAB(
     34) INT (CC)
1170  PRINT "HVAC AUX."; TAB( 12)
      INT (F2); TAB( 22) INT (FA)
     ; TAB( 34) INT (F3)
1180  PRINT "LIGHTS"; TAB( 12) INT
     (LF); TAB( 22) INT (LB); TAB(
     34) INT (LC)
1200  PRINT "DHW"; TAB( 12) INT (
     DF); TAB( 22) INT (DB); TAB(
     34) INT (DC)
1220  PRINT : PRINT "TOTAL"; TAB(
     12) INT (HF + C2 + LF + DF +
     F2); TAB( 22) INT (HB + CF +
     LB + FA + DB); TAB( 34) INT
     (CH + CC + F3 + LC + DC)
1240  PR# 0
1250  PRINT "PRINT VARIABLE LIST?
     ": INPUT "  ENTER Y OR N: ";
     VL$
1260  IF VL$ <  > "Y" THEN 1500
1270  PR# 1
1280  PRINT : PRINT : PRINT "LIST
      OF VARIABLES": PRINT "-----
     -------------"
1290  PRINT "HEAT LOSS COEFFICIEN
     T= "; INT (UA);" BTU/HR-F"
1300  PRINT "WINTER SOLAR HEAT GA
     IN= ";SH;" MMBTU"
1310  PRINT "SUMMER SOLAR HEAT GA
     IN= ";SS;" MMBTU"
1320  PRINT "WINTER INFILTRATION
     CFM= ";IW%
1330  PRINT "SUMMER INFILTRATION
     CFM= ";IS%
1340  PRINT : PRINT "SEAS.HEATING
      EFFICIENCY= ";HE
1350  PRINT "SEAS.COOLING COP= ";
     CE
1360  PRINT "VENTILATION CFM= ";V
     C%
1370  PRINT "VENTILATION HRS/WK=
     ";HV
1375  PRINT "HVAC AUXILIARY ENERG
     Y= ";FA;" MMBTU"
1380  PRINT "DHW SEAS.EFFICIENCY=
      ";WE
1390  PRINT "WEEKLY DHW USE= ";GA
     %;" GAL."
1395  PRINT
1400  PRINT "ROOM LTNG. KW= ";KR
1410  PRINT "CORRIDOR LTNG. KW= "
     ;KC
1420  PRINT "WINTER LTNG. HEAT GA
     IN= ";LW;" MMBTU"
1430  PRINT "SUMMER LTNG. HEAT GA
     IN= ";LS;" MMBTU"
1435  PRINT
1440  PR# 0
1500  END
```

Section R: Impact of Retrofit Packages on Key Parameters:

This section shows the results of the method used by Energyworks to calculate the savings from each retrofit package. By examining which building parameters are affected by individual retrofits, they calculated revised parameter values and then calculated revised energy use from these. The parameter abbreviations used in the table are as follows:

GA% = Domestic hot water consumption, gallons/week

LW = Total lighting energy, heating season (for heat gain calcs.), MMBTU

LS = Total lighting energy, cooling season

HE = Seasonal efficiency of heating system

CE = Seasonal efficiency of cooling system

WE = Seasonal efficiency of domestic hot water system

FA = Total annual HVAC auxiliary energy, MMBTU

HD% = Heating degree-days (effective degree-days altered by thermostat measures)

CD% = Cooling degree-days (effective CD% altered by enthalpy control)

UA = Building heat loss coefficient, BTU/hr-F

SW = Total solar heat gain, heating season (MMBTU)

SS = Total solar heat gain, cooling season (MMBTU)

IW% = Average infiltration volume, heating season (cubic ft/minute)

IS% = Average infiltration volume, cooling season (cubic ft/minute)

VC% = Ventilation volume, cubic ft/minute

HV = Operating hours of ventilation system, hr/week

KR = Peak installed room lighting load (KW)

KC = Peak installed corridor lighting load (KW)

P/U 1

PARAMETER LIST

	CAV/AIR/SFL				CAV/H2O/SFL			
	BASE	L	M	H	BASE	L	M	H
HD%	3628	3371	3371	3371	3628	3371	=	=
CD%	2337	=	=	=	2337	=	=	=
UA	1677	123.2	915	866	1677	1064	939	866
SW	11.1	=	=	=	11.1	=	=	=
SS	11,3	=	=	=	11,3	=	=	=
IW%	76	46	32	32	76	46	32	32
IS%	58	35	24	24	58	35	24	24
VC%	0	0	0	0	0	0	0	0
HV	0	0	0	0	0	0	0	0
KR	1.4	=	=	=	1,4	=	=	=
KC	0	0	0	0	0	0	0	0
GA%	294	147	=	=	294	147	=	=
LW	36	=	=	=	36	=	=	=
LS	35	=	=	=	35	=	=	=
HE	.58/.65	=	.62/.68	=	.58/.65	=	.62/.68	.68/.71
CE	2,03	=	=	=	1,52	=	2,27	=
WE	.47	.494	.652	=	.47	.494	=	=
FA	5,6	4,5	4,5	4,5	1.0	1.0	1.0	1,0

P/U 1

PARAMETER LIST

	CAV/DEZ/SFL				MBW/AIR/SFL			
	BASE	L	M	H	BASE	L	M	H
HD%	3628	3371	=	=	3628	3371	=	=
CD%	2337	=	=	=	2337	=	=	=
UA	1677	1064	890	=	922	922	796	587
SW	11.1	=	=	=	5.3	=	=	=
SS	11.3	=	=	=	3.3	=	=	=
IW%	76	46	32	32	45	27	19	19
IS%	58	35	24	24	35	21	15	15
VC%	0	0	0	0	0	0	0	0
HV	0	0	0	0	0	0	0	0
KR	1.4	=	=	=	1.4	=	=	=
KC	0	0	0	0	0	0	0	0
GA%	294	147	=	=	294	147	=	=
LW	36	=	=	=	36	=	=	=
LS	35	=	=	=	35	=	=	=
HE	1.0	=	=	1.55	.58/.65	=	.62/.68	=
CE	1.52	=	2.27	2.27	2.03	=	=	=
WE	.95	.98	=	=	.47	.494	=	=
FA	.0	0	0	0	5.6	4.5	4.5	4.5

P/U 1

PARAMETER LIST

	MBW/H2O/SFL				MBW/DEZ/SFL			
	BASE	L	M	H	BASE	L	M	H
HD%	3628	3371	=	=	3628	3371	=	=
CD%	2337	=	=	=	2337	=	=	=
UA	922	922	796	599	922	922	673	599
SW	5,3	=	=	=	5,3	=	=	=
SS	3,3	=	=	=	3,3	=	=	=
IW%	45	27	19	19	45	27	19	19
IS%	35	21	15	15	35	21	15	15
VC%	0	0	0	0	0	0	0	0
HV	0	0	0	0	0	0	0	0
KR	1,4	=	=	=	1,4	=	=	=
KC	0	0	0	0	0	0	0	0
GA%	294	147	=	=	294	147	=	=
LW	36	=	=	=	36	=	=	=
LS	35	=	=	=	35	=	=	=
HE	,58/,65	=	,68/,70	=	1.0	=	=	1,55
CE	1.52	=	2,27	2,27	1,52	=	2.27	2,27
WE	,47	,494	=	=	,95	.98	=	=
FA	1.0	1.0	1,0	1.0	0	0	0	0

P/U 5

PARAMETER LIST

	CLAD/AIR/LG MULTI				CLAD/H2O/LG MULTI			
	BASE	L	M	H	BASE	L	M	H
HD%	3628	3371	=	=	3628	3371	=	=
CD%	2337	2132	=	=	2337	=	=	=
UA	23317	=	21494	10216	23317	=	19956	10682
SW	306	306	=	=	306	306	=	=
SS	312	281	=	=	312	281	=	=
IW%	1376	=	=	826	1376	=	826	=
IS%	1105	=	=	663	1105	=	663	=
VC%	6000	=	=	=	3525	=	=	=
HV	168	=	=	=	168	=	=	=
KR	100	53	=	=	100	53	=	=
KC	20	6.6	=	=	20	6.6	=	=
GA%	29400	14700	=	=	29400	14700	=	=
LW	648	322	=	=	648	322	=	=
LS	630	313	=	=	630	313	=	=
HE	.54/.58	.57/.60	=	=	.54/.58	.64/.66	.70/.72	.72/.73
CE	2.26	2.825	2.99	=	1.52	=	2.27	=
WE	.54	.65	=	=	.54	.65	=	=
FA	385	308	=	=	108	=	=	=

P/U 5

PARAMETER LIST

	CLAD/DEC/LGMULTI							
	BASE	L	M	H	BASE	L	M	H
HD%	3628	3371	=	=				
CD%	2337	=	=	=				
UA	23317	=	19956	10682				
SW	306	306	=	=				
SS	312	281	=	=				
IW%	1376	=	826	=				
IS%	1105	=	663	=				
VC%	3525	=	=	=				
HV	168	=	=	=				
KR	100	53	=	=				
KC	20	6.6	=	=				
GA%	29400	14700	=	=				
LW	648	322	=	=				
LS	630	313	=	=				
HE	1.0	=	1.55	=				
CE	1.52	=	2.27	=				
WE	.95	1.81	=	=				
FA	0	0	0	0				